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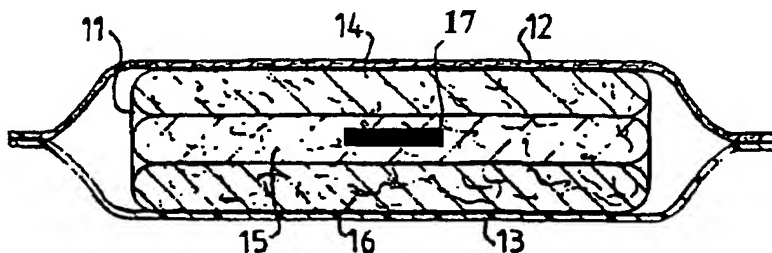
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(54) Title: SENSORING ABSORBING ARTICLE



(57) Abstract: A disposable sensing absorbent structure for detecting wetness is provided, comprising at least one absorbent layer and at least one sensing device comprising a magnetoelastic film. Such an absorbent structure enables means and methods for monitoring the status, e.g. wetness at least one biological and/or at least one chemical analyte, in an absorbent article. A change in status, such as wetness,

may reflect an event, such as urination or a faeces event. Also included are methods for detecting wetness at least one biological and/or at least one chemical analyte, using the sensing absorbent structure according to the invention.

## SENSING ABSORBING ARTICLE

### TECHNICAL FIELD

This invention relates to a sensing absorbent structure, comprising at least one absorbent layer and at least one sensing device comprising a magnetoelastic film. Also provided is a sensing absorbent system and a method for detecting wetness, at least one biological analyte and/or at least one chemical analyte in an absorbent structure.

### 10 BACKGROUND OF THE INVENTION

#### *Disposable absorbent articles*

Absorbent articles, such as diapers for infants and adults, sanitary napkins, and adult incontinence briefs, are well known within the art and used widely. Most such products today are used on a single-use basis. The single-use basis of such disposable products have led to the development of a wide assortment of different products to meet specific requirement(s), e.g. in infant and toddler care, as well as in adults suffering from incontinence. The main purpose of such absorbent articles is normally to absorb, retain and isolate body wastes, i.e. urine, faeces, or blood.

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#### *Detection of an event*

One specific group of absorbent articles may respond to an event, such as urination or defecation, after absorption onto or into the product. The response can be a signal after the event has occurred and is based on a measure of, e.g. wetness, or temperature. The signal of an event can give the user or nursing aid a feedback that an event has occurred, to ease the handling for the user or care taker/nursing personnel.

US 5348761 describes a moisture/wetness-detecting sensor that utilises a swellable plastic having conductive additives. The sensor swells in operation in response to moisture, which, in turn, increases resistance in the sensor. All embodiments show connecting wires attached to electrodes for monitoring the moisture/wetness.

#### *Chemical detection*

One group of absorbent articles known in the art comprises chemical reactive means, i.e. sensors, to detect various chemical substances such as pH or ions, glucose, etc., in the body waste(s), e.g. faeces or urine. The detection of such chemical substances will give the user or nursing aid feedback that an event has occurred. Most chemical sensors rely on a colour change to enable detection of e.g.

pH or different ions. Monitoring of such colour changes often also require that the user, e.g. an elderly incontinent patient or an infant, be physically displaced, e.g., by turning to one side.

Furthermore, chemical compounds that give colour changes are often toxic or  
5 irritating to the skin. Therefore, the incorporation of such compounds in absorbent articles is hardly appropriate, with respect to both environmental aspects as well as the user's health.

### *Biodetection*

10 Another group of absorbent articles includes means for detecting bio-molecules, such as proteins, hormones, microorganisms, such as e.g. bacterias or viruses, glucose, or bacterial toxins. Several of these also detect and target potentially pathogenic microorganisms, such as bacteria, viruses, fungi, and parasites, e.g. protozoans. Detection of such biomolecules such as microorganisms can give  
15 indications of a potential health and/or nutritional status, as well as detecting an event, such as urination, or defecation.

In WO 00/00233 a disposable article is disclosed to be fitted to a wearer comprising a biosensor with a biorecognition element to detect a biological analyte in body waste.

20 WO 98/27417 describes a biosensing device for detecting and quantifying analytes present in a medium. The analyte is detected via an image produced as a diffraction pattern.

### *Magnetoelastic sensors*

25 Magnetoelastic sensors have been described by Grimes et al., (Biomedical Microdevices, 2:51-60, 1999).

When a magnetic field is applied to, for instance, a ferromagnetic material, the dimension of the material changes. This effect is called magnetostriction. The size of the dimensional changes of the material is governed by the magnetostriction  
30 constant.

When exposed to an externally applied magnetic pulse, the material generates magnetic flux with a characteristic resonant frequency. The magnetic flux can be detected remotely by a pick-up coil. The changes in resonant frequency can be monitored so as to measure or detect multiple environmental parameters. Measure-  
35 ments of temperature, pressure, viscosity, using this method are described in Grimes et al., (Biomedical Microdevices, 2:51-60, 1999). Through the inclusion of a glucose-responding mass changing polymer, measurements in-situ of glucose levels can be performed.

It is also possible to excite the material with a continuous magnetic field showing a frequency corresponding to the magneto-acoustic resonant frequency and measure the response from the material. At this resonant frequency the response from the material is maximal. It also possible to excite the material with a continuous magnetic field with a frequency close to the magneto-acoustic resonance frequency in pulses and measure the damped magnetic response from the material between the pulses.

#### *Magnetoacoustic effect*

10        When a magnetic material is excited by a magnetic field, it stores magnetic energy in a magnetoelastic mode. When the field is switched off, the material shows damped oscillation with a specific frequency, the latter being the magnetoacoustic resonant frequency.

#### 15    *General issues concerning sensors in absorbent articles*

Sensors to be included in absorbent articles should preferably be inexpensive, to enable disposable single-use of the absorbent articles. Also, they need to be reliable and able to withstand the particular milieu found in a very specific environment, such as a diaper.

20        Also, the sensor has to be safe for the user and the nursing aid, i.e., not evoke any skin irritation or toxicity effects in either party. Furthermore, it is recommended that the sensor be environmentally friendly, to make such an absorbent product disposable without any restrictions in waste handling. Environmental related concerns are becoming more and more important to our society today, and are  
25    respectively lobbied for and implemented by international environmental regulatory agencies and national governments.

Several of the above mentioned sensors require direct physical connections to the sensor, and/or the incorporation of an electronic circuit. This is inconvenient for the user in many aspects, not allowing for remote detection and monitoring, which  
30    will limit the usefulness of the sensor in several aspects. The electronic circuit requires that a power supply be incorporated into the absorbent article, which raises a health question for the user or nursing aid. Moreover, it is bulky to incorporate into the absorbent article. Also, the incorporation of one or more batteries into a disposable product is an environmental hazard, since battery disposal requires  
35    special recycling protocols.

The monitoring of an event should be done simply, to enable the user or nursing aid to easily register the body waste status, without having to physically displace the user in any way.



US 5821129 discloses a sensor that allows for a remote, continuous magnetochemical detection of various chemical species in e.g. exhaust pipes, flumes, chemical baths or body implants.

WO 0079497 describes the use of a radiofrequency resonant circuit sensing device and its use for detection of fluid leaks from containers or bodies, e.g., fluid drainage from a human suffering from urinary and/or faecal incontinence. The sensor device relies on a coil which can receive the fluid and which responds by shortcircuiting in a "one hit" event after, e.g., urination.

It is thus highly desirable in light of the aforementioned problems to develop means and methods for monitoring the status in an absorbent article, which, thus, reflect the status of the user in an easily detected, inexpensive, disposable way, and which also avoids earlier problems associated with the prior art means and methods. In this respect, the present invention addresses this need and interest.

## SUMMARY OF THE INVENTION

In view of the foregoing disadvantages known in the art when monitoring status in an absorbent article, the present invention provides a sensing absorbent structure able to provide information about the status of the absorbent article in an easily monitored, inexpensive, disposable way. In some cases the status of the absorbent article thus reflects the status of the user.

One object of the present invention is to provide a sensing absorbent article for detecting wetness.

One further object of the present invention is to provide a sensing absorbent article for detecting at least one biological and/or at least one chemical analyte.

Thus, the present invention provides an absorbent structure, comprising at least one absorbent layer and at least one sensing device comprising a magnetoelastic film.

The absorbent structure according to the invention is a structure wherein the at least one layer comprises 0-95% of superabsorbent material.

The magnetoelastic film in the absorbent structure according to the invention, oscillates with a magnetoacoustic resonant frequency, after the magnetoelastic film is excited in a magnetic field and when the magnetic field is switched off.

Furthermore, the at least one sensing device in the absorbent structure according to the invention may be 1-20 sensing device(s).

The magnetoelastic film in the absorbent structure according to the invention is a thin film, and the film is selected from the group consisting of magnetostrictive material, such as magnetoelastic material, soft magnetoelastic material, amorphous magnetoelastic material, and mixtures thereof.

Also, the present invention provides an absorbent article such as a diaper, a diaper of pant type, incontinence garment, sanitary napkin, wipe, towel, tissue, bed protector, wound or sore dressing, or similar product comprising the absorbent structure according to the invention, a fluid permeable, and an essentially fluid-impermeable bottom sheet.

In another aspect, the present invention provides a sensing absorbent system, comprising the absorbent structure according to the invention, optionally being part of the absorbent articles according to the invention, and a hand held unit, comprising an excitation coil generating a magnetic field to magnetize said magnetoelastic film and, optionally, a pick-up coil to detect the magnetoacoustic resonant frequency.

In a further aspect, a method for detecting wetness, at least one biological and/or at least one chemical analyte is provided. Such a method comprises the steps of

- a) providing an absorbent structure according to the invention, an absorbent article according to the invention, or the system according to the invention,
- b) applying a magnetic field,
- c) exciting the magnetoelastic film in the at least one sensing device in the absorbent structure,
- d) switching the magnetic field off,
- e) recording magnetoacoustic resonant frequency,
- f) optionally repeating step b) to e), and
- g) detecting changes in the magnetoacoustic resonant frequency, so as to detect wetness/moisture/humidity, at least one biological and/or at least one chemical analyte in the absorbent structure.

#### SHORT DESCRIPTION OF DRAWINGS

**Fig. 1** shows an absorbent structure 11 according to the invention, suitable for an absorbent article, such as a diaper. The absorbent structure 11 is in a conventional manner enclosed between a fluid-permeable layer 12 which may comprise a soft non-woven material, a perforated plastic film or the like and is intended to lie proximal to the wearer when used, and a fluid-impermeable bottom sheet 13. The sheets 12 and 13 have parts, which may extend beyond the absorbent body 11. The absorbent structure shown in figure 1a and 1b has at least one sensing device comprising a magnetoelastic film 17 placed on different positions figure 1a and b,

**Fig. 2** shows a magnetoelastic film, an excitation coil and a pick up coil. The magnetoelastic film is magnetized by the excitation coil with a pulsed magnetic

field. The magnetic film becomes magnetized and the response from the film is detected by the pick-up coil.

Fig. 3 shows the experimental set-up for detecting the magnetoacoustic effect. The outer coil is the excitation coil. The inner coil is the pick up coil positioned around the METGLAS<sup>®</sup> film. The coil in the middle is used to counteract the field from the excitation coil.

Fig. 4a-f shows five different embodiments for a sensor detecting wetness, at least one biological and/or at least one chemical analyte using the magnetic METGLAS<sup>®</sup> film.

Fig. 5 shows a drawing of the handheld unit that may be used to excite the magnetoelastic film, detect the response from the film and present the result for the user. It contains a signal generator that generates signals that is sent to the excitation coil and a detection circuit that receives and detects the signals from the pick-up coil. The presentation unit presents the result for the user in a proper way.

Fig. 6A-C shows a diaper comprising the absorbent structure according to the invention, a front-part, a back-part, a crotch-part between the front and back-parts.

Fig. 6A is a diaper with one sensing device 20 in the absorbent structure,

Fig. 6B is a diaper with five sensing devices 20 placed in different parts of the absorbent structure,

Fig. 6C is a diaper with four sensing devices 20 in the front of the diaper still in the absorbent structure,

Fig. 7A is a perspective view of a simplified embodiment of a pants type diaper in an unassembled state with one sensing device 35 placed in the absorbing structure,

Fig. 7B is a perspective view of a simplified embodiment of a pants type diaper, in an assembled or ready-to-wear state,

Fig. 7C shows the same as in 7A, but with four sensing devices 35 placed in the absorbing structure,

Fig. 8 shows a tampon structure cut open to show a sensing device 39 placed in the absorbing structure of the tampon,

Fig. 9 shows a wipe with a plurality of individual sheets,

Fig. 10 shows an absorbent sensing unit,

Fig. 11 shows the experimental set-up in the experiments with a circular excitation coil and an eight-shaped pick-up coil,

Fig. 12 shows a diaper placed in the experimental set-up. The pick-up coil is underneath the diaper (not visible),

Fig. 13 shows a frequency shift from  $5.93 \times 10^4$  Hz to  $5.75 \times 10^4$  Hz when the synthetic urine is detected by the wetness sensor coated with polyvinylpyrrolidone (PVP),

**Fig. 14** shows a frequency shift from  $5.83 \times 10^4$  Hz to  $5.69 \times 10^4$  Hz when the synthetic urine is detected by the wetness sensor coated with cross-linked polyvinyl-alcohol (PVOH),

**Fig. 15** shows a frequency shift from  $5.71 \times 10^4$  Hz to  $5.63 \times 10^4$  Hz when the synthetic urine is detected by a wetness sensor coated with sodium chloride (NaCl),

**Fig. 16** shows a frequency shift from  $5.81 \times 10^4$  Hz to  $5.74 \times 10^4$  Hz when the AA-device is attached to the absorbent structure 27 cm from the centre front of the liquid impermeable backing sheet,

**Fig. 17** shows a frequency shift from two different sensors placed at different positions in the absorbent structure,

**Fig. 18** shows a frequency shift from  $5.76 \times 10^4$  Hz to  $5.66 \times 10^4$  Hz when using a sensor without encapsulation of the Metglas film, and

**Fig. 19** shows a frequency shift from  $6.00 \times 10^4$  Hz to  $5.95 \times 10^4$  Hz when using a sensor without a permanent magnet.

**Fig. 20** shows a frequency shift from 58680 Hz to 58480 Hz when using Metglas coated with a cationic polymer.

**Fig. 21** shows a frequency shift from 58140 Hz to 57980 Hz when using Metglas coated with a colloidal suspension.

**Fig. 22** shows a frequency shift from 57899 Hz to 58060 Hz when using Metglas coated with a hydrophobic polymer.

**Fig. 23** shows a frequency shift from 58665 Hz to 58428 Hz when using Metglas coated with a cationic polymer.

**Fig. 24** shows a close-up on the centre of the experimental setup, showing a device under test 1 and the figure of eight shaped excitation/detection coil 2.

**Fig. 25** shows an overview of the experimental setup in experiment 7-11. The device under test 1 is placed horizontally in the centre of the setup. Below the sample 1 is a figure of eight shaped pickup/detection and excitation coil 2. The outermost coil-pair is a Helmholtz coil 3 used for applying a homogenous magnetic field. The concentric coil 4 pair within the Helmholtz coil 3 was not used in these measurements. A magnetoelastic detection unit 5 is seen below the coils. The magnetoelastic detection unit is connected 6 to the excitation/detection coil 2.

## DETAILED DESCRIPTION OF THE INVENTION

### Definitions

As used herein, the term "absorbent article" refers to a device that absorbs, retains and contains body waste or body exudates. The device is placed against or in the proximity of the body of a wearer to absorb, retain and contain the various body waste or body exudates from the body.

The term "disposable" is herein intended to mean an absorbent article that is not intended to be laundered, restored or reused as an absorbent article. Such an absorbent article is intended to be discarded after a single use. The single use does not exclude the product from being recycled, made compost or otherwise disposed of in an environmentally compatible manner.

The term "sensor" is herein intended to mean a device that is capable of detecting an event or a parameter that is associated with an event. A parameter associated with an event is any measurable signal that correlates with the occurrence of an event within the framework of the system, i.e., a signal caused by the waste, the wearer, or a component thereof. Sensors include anything that responds to one or more specific inputs.

The term "sensing" or "sensing" is herein intended to mean means and methods capable of detecting an event or a parameter that is associated with an event, e.g. via a sensing device.

The term "wetness" is herein intended to mean the condition of being wet, humid, damp or moisture or the condition of containing or being covered by a liquid.

The term "diaper" is herein intended to mean an absorbent article generally worn about the lower part of the torso by infants, toddlers and incontinent persons.

The term "user" is herein intended to mean a) the user of an absorbent article or b) the nursing aid of the user of an absorbent article.

The term "magnetostriction" refers to a common phenomena for magnetic materials. Magnetostriction means that when a magnetic material is magnetized, the dimensions of the material change. The size of the dimensional change depends on temperature, magnetization in the material and of course, on the material properties. Magnetostriction is due to the interaction between the atomic magnetic moments in the material.

The term "magnetoacoustic resonant frequency" refers to an oscillation frequency. Such a frequency occurs when a magnetic material is excited by a magnetic field and stores magnetic energy in a magnetoelastic mode. When the magnetic field is switched off, the material shows damped oscillation with a specific frequency, referred to as the magnetoacoustic resonant frequency.

The term "biological analyte", "biomolecule" or "bio-analyte" is herein intended to mean biologically derived material.

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#### *The absorbent structure*

In normal use, an absorbent structure in an absorbent article, such as a diaper, a diaper of pant type, incontinence garment, sanitary napkin, bed protector, wound or sore dressing, serves to absorb, retain and isolate body wastes or body exudates,

for example, urine, faeces, blood, menstruation blood, fluid matter from wounds and sores, rinsing fluid and saliva.

As revealed above, the present invention relates to a sensing absorbent structure, wherein the sensor part will enable means and methods for monitoring status, e.g. by measuring wetness or humidity, in an absorbent article after or at, e.g.,  
5 an urination event which, thus, will reflect the status of the absorbent structure in an easily monitored, inexpensive, and disposable way. A change in status, such as wetness or humidity, may reflect an event, such as urination or a faeces event. Easily monitored means include a remote access to the status, e.g. wetness status, without  
10 moving the user in any way and, may also, enable continuous monitoring of the status, e.g. wetness status, nutritional status and/or health status over time.

According to the invention, an absorbent structure is provided, comprising at least one absorbent layer and at least one sensing device comprising a magnetoelastic film.

15 Further embodiments include wherein the at least one absorbent layer comprises an acquisition layer, and storage layer(s), and optionally one or more wicking layer. The acquisition layer is intended to take up fluid and disperse said fluid to the wicking and storage layer.

In one embodiment, the absorbent structure is a disposable absorbent  
20 structure.

Another embodiment includes an absorbent structure, wherein at least one of the layers comprises 0-100% superabsorbent material.

In further embodiments, the layer may comprise 0-95%, 20-100%, 0-30%, 20-90%, or 30-40% superabsorbent material.

25

*An absorbent structure to be used in a diaper type product or bed protector*

One embodiment of the invention includes an absorbent structure according to the invention, wherein the absorbent layer comprise at least one acquisition layer, and at least one storage layer. Such an absorbent structure may be incorporated in a  
30 diaper, pants type diaper, incontinence garment, sanitary napkin and similar product.

Figure 1a and b shows two embodiments of an absorbent structure 11 according to the invention, suitable for an absorbent article, such as a diaper. The absorbent structure 11 is, in a conventional manner, enclosed between a fluid-permeable layer 12 which may comprise a soft non-woven material, a perforated  
35 plastic film or the like and is intended to lie proximal to the wearer when used, and a fluid-impermeable bottom sheet 13. The sheets 12 and 13 have parts, which may extend beyond the absorbent body 11. The sheets are joined together at these protruding parts. The bottom sheet 13 is comprised of a suitable plastic material, for instance polyethylene, e.g. in a laminate, a laminate between a non-woven and

polypropylene, a laminate between a polyolefin and a non-woven. It may also be filled with an organic filler. It will be understood, however, that other known materials may be used for the top and bottom sheets within the scope of the invention.

- 5       The absorbent structure is comprised of two or more layers, an upper acquisition layer 14, one or more wicking layers 15, and one or more storage layers 16. The layers may be comprised of conventional cellulose fibre material. The purpose of the acquisition layer is to rapidly receive a quantity of a fluid or solid, or mixture thereof, body waste or body exudates, such as urine, faeces, blood,
- 10       menstruation blood, fluid matter from wounds and sores, rinsing fluid and saliva. The fluid shall be loosely held in the fibre structure and quickly drained therefrom. The acquisition layer is comprised of dry-formed and wet-formed material in accordance with the invention and is comprised of an open structure of low density and may contain 0-30% superabsorbent material (SAP). The SAP in the acquisition
- 15       layer 14 will preferably have a high gel strength, so that an open three-dimensional fibre structure will be retained in this layer after becoming wet. A suitable density range for the acquisition layer 14 is  $0.30\text{-}1.0\text{ g/cm}^3$ . A suitable weight per unit area range for the acquisition layer 14 is  $20\text{-}1200\text{ g/m}^2$ .

- The main purpose of the wicking layer is to transport the fluid received in the
- 20       acquisition layer 14 efficiently to the storage layer 16, located beneath the wicking layer 15 and the storage layer 16, to ensure that the greatest part of the storage layer 16 is utilised for absorption purposes. The wicking layer therefore has a relatively low superabsorbent content. A suitable superabsorbent content, in the case of the wicking layer 15, may be 0-20% while a suitable density range may be  $0.18\text{-}1.0$
- 25        $\text{g/cm}^3$ . A suitable weight per unit area range for the wicking layer 15 may be  $50\text{-}1500\text{ g/m}^2$ .

- The purpose of the storage layer 16 is to absorb and bind the fluid, which is dispersed to the storage layer 16 through the wicking layer 15. The storage layer 16 may therefore have a high density. Suitable density values may be  $0.18\text{-}1.0\text{ g/cm}^3$ ,
- 30       while a suitable superabsorbent content may be 20-100%. Still a further embodiment is wherein a suitable superabsorbent content may be 30-40%. A suitable weight per unit area range in the case of the storage layer 16 is  $100\text{-}1500\text{ g/m}^2$ .

- The wicking layer 15 and the storage layer 16 may optionally be combined to form a single layer. In this case, the single layer will have a high superabsorbent
- 35       content and a high density. Suitable density values may be  $0.125\text{-}1.0\text{ g/cm}^3$ , while a suitable superabsorbent content may be 20-90%. A suitable weight per unit area range in the case of a combined wicking and storage layer is  $100\text{-}2000\text{ g/m}^2$ .

      When the wicking layer 15 and the storage layer 16 are combined, the superabsorbent content of the layer can be varied throughout the product, so as to

obtain a superabsorbent gradient on the depth, length and/or the breadth direction of the product.

The absorbent structure may comprise one layer or several layers, such as two-, three- or more layers.

- 5 The various layers may have different forms and sizes. Normally, the absorbent structure is combined with some form of elasticitation in, e.g., the crotch region of the product if a diaper, in order to improve product efficiency.

According to the invention, an absorbent structure is provided comprising at least one absorbent layer and at least one sensing device comprising a  
10 magnetoelastic film 17. In figure 1a and 1b, the position of the at least one sensing device 17 is shown. In the two embodiments shown, the sensors are placed at different depths in the absorbent structure. Still, within the scope of the invention other positions and number of sensors are contemplated and are further discussed below.

15

*An absorbent structure to be used in a bed protector, wipe, towel or tissue*

One embodiment according to the invention is an absorbent structure, wherein the at least one absorbent layer comprise at least one drying layer, and wherein the layers optionally comprises a plurality of individual sheets and bonding  
20 means for joining said individual sheets. The plurality of sheets allows production of e.g. wipes, towels, bed protectors and tissue of a correct, i.e., desired, thickness that may differ from case to case due to different specific usage.

Figure 9 shows one embodiment of an absorbing structure according to the invention comprising at least one sensing device detecting wetness, wherein the at  
25 least one absorbent layer comprise at least one drying layer. The figure shows a fabric for removing undesirable matter from an object by wiping, said fabric comprises an absorbing structure according to the invention with a plurality of individual sheets, and bonding means for joining said individual sheets together.

Said fabric may be a wipe for domestic or commercial uses, or for industrial  
30 or hygienic applications. Furthermore, said fabric may be oil wipes useful for wiping oils, solvent wipes useful for solvent cleaning, wet wipes useful for wet wiping, or any other wipe suitable for hygienic or household applications or suitable for removing any undesirable matter.

Said wipe suitable for hygienic or household applications may be e.g.  
35 household items such as hygienic wipes, kitchen towels, napkins or industrial wipes.

Said undesirable matter may be any fluid, e.g. domestic or industrial spills, high viscosity liquids, water, oil, solvents, chemicals or similar, any particles, any dust, any dirt, e.g. grease, stain or grime, or similar, or any kind of household dirt.

Said object may be any object needing removal of undesirable matter, e.g., a



whole body or any body part, such as hands, face, feet or similar, any part or any surface of e.g., machines, vehicles, printing plates, tools, floors, walls, furniture, tables or similar.

By "removing undesirable matter from an object by wiping" it is meant that  
5 undesirable matter from an object is removed by wiping, rubbing, polishing, stroking or similar, using said fabric.

Each individual sheet may comprise any suitable natural or synthetic material, e.g., of a woven or nonwoven type, tissue or similar, said sheet may be homogeneously or heterogeneously shaped of fibres described below.

10 Said individual sheet may, for example, comprise fibres of polyamide, polyester, polypropylene, polyethylene or their co-polymers, or thermoplastic fibres, core-sheath conjugated fibres consisting of a polypropylene core and a polyethylene sheath, copolyester fibres or undrawn polypropylene fibres, or continuous filament, e.g., polyethylene terephthalate continuous filament, or, polyurethane, polyurea,  
15 cellulosic or cotton fibres, peat or polylactides. Moreover, said individual sheet may comprise two or several of the components listed herein or any mixture thereof.

Said bonding means for joining said individual sheets together may comprise, e.g., techniques from conventional ply-bonding or any conventional gluing techniques i.e. use of hot or cold glue systems, and spot or strip gluing.

20 According to one embodiment of the present invention, said plurality of individual sheets may have coinciding edges and said plurality of individual sheets may be bonded together by said bonding means at said edges.

Another embodiment of the present invention may be wherein said plurality of individual sheets is bonded together by said bonding means in spots or strips.

25 All variants of bonding as disclosed herein may be achieved by using techniques from conventional ply-bonding or any conventional gluing techniques i.e. use of hot or cold glue systems, and spot or strip gluing.

The individual sheets may comprise a nonwoven material wherein said nonwoven material may, for example, be prepared by meltblowing, spunbonding or  
30 carding processes, and said nonwoven material may be further treated by, for example, fluid injection entanglement or any other entanglement, ultra sound or embossment. Said nonwoven material may be prepared from, for example, synthetic fibres, e.g., polymeric fibres or thermoplastic polymeric fibres or similar, natural fibres, e.g., wood pulp fibres, cotton fibres or linen fibres or other man made  
35 cellulose fibres such as viscose or rayon.

In a further fabric according to the present invention said individual sheets may comprise a tissue material, wherein said tissue material covers fibrous material based on cellulose or cellulose in combination with synthetic fibres.

The individual sheets may be heterogeneous. A sheet is said to be hetero-

geneous when said sheet is composed of more than one material, wherein the materials may have different characteristics. Each heterogeneous individual sheet may, for example, comprise an absorbing layer and a liquid barrier layer, wherein said absorbing layer of any exposed individual sheet may constitute the outside of  
5 said fabric. Said liquid barrier layer may be any liquid impermeable layer and may, for example, comprise a thermoplastic film.

Figure 9 shows an absorbent structure 1, which comprises a plurality of individual sheets 2, and a body 3. Said individual sheets 2, have coinciding edges and said coinciding edges have bonding means 4, for joining said individual sheets  
10 2, together. Each of said individual sheets 2, comprises an absorbing layer 5, and a liquid barrier layer 6. Moreover, in figure 9, a single individual sheet 7, is also shown which is partly removed from said fabric 1.

According to the invention, at least one sensing device is placed in the absorbing structure. Said sensing device may be placed in any of the at least one  
15 absorbing layer. The exact placing of the sensors depends on the particular usage of the wipe, tissue, towel or similar product, and on how the matter to be removed is absorbed, etc. Each embodiment thus has to be considered individually when placing the sensors in an optimal way both in respect to the exact position of the sensor(s) and the number of sensors.

20

*The sensing device detecting wetness, at least one biological and/or at least one chemical analyte*

When a magnetic field is subjected to, for instance, a ferromagnetic material, the dimension of the material changes as an effect of said magnetostriction. The size  
25 of dimensional change of the material is governed by a magnetostriction constant.

When a magnetic material is excited by a magnetic field, it stores magnetic energy in a magnetoelastic mode. When the field is switched off the material shows damped oscillation with a specific frequency, the magnetoacoustic resonant frequency. These oscillations give rise to a magnetic flux that varies in time, which  
30 can be remotely detected by a pick-up coil.

Magnetostriction can be observed in many materials, for instance, in iron, nickel, cobalt, rare earth metals as well as in different alloys such as iron-nickel alloys, ferrites, e.g. spinel type ferrites ( $\text{Fe}_3\text{O}_4$ ,  $\text{MnFe}_2\text{O}_4$ ), silicon-iron alloys, and many other different alloys.

35 Further embodiments may use soft magnetic materials, alloys or mixtures thereof.

Even further embodiments may use amorphous magnetic material, alloys or mixtures thereof, due to the fact that amorphous magnetic material is very easy to magnetically saturate and show small magnetic anisotropy. In alloy amorphous

magnetic material, the magnetostriction is also present and the amount of magnetostriction depends on the exact composition of the alloy. Examples of amorphous alloys are metglases such as  $\text{Fe}_{40}\text{Ni}_{38}\text{Mo}_4\text{B}_{18}$ , e.g. Metglas 282MB™ (Honeywell Amorphous Metals, Pittsburg, PA, USA),  $(\text{FeCo})_{80}\text{B}_{20}$ ,  $(\text{CoNi})_{80}\text{B}_{20}$ ,  
5  $(\text{FeNi})_{80}\text{B}_{20}$ .

One embodiment uses METGLAS® material from Honeywell (Honeywell Amorphous Metals, Pittsburg, PA, USA) as the magnetoelastic material, such as METGLAS® 2826MB.

One way of further enhancing the magnetostrictive effect is to include a  
10 magnetic bias field. Figure 4e shows one embodiment with such a bias field with two electrodes included. The two electrodes in figure 4e is of Cu and Al, respectively. In one embodiment of the invention, such a magnetic bias field is included. A magnetic bias field has an optimal magnetic bias field, giving an optimal magnetoacoustic effect, and further giving an optimal signal from the  
15 magnetoacoustic effect (Grimes et al., *Sensors and Accutators*, B71:112-117, 2000). In one embodiment, the magnetic bias field is generated by a permanent magnetic film, placed in connection with the magnetoelastic film.

According to the invention, described absorbent structure includes at least one sensing device comprising a magnetoelastic film. Suitable magnetoelastic films  
20 may be any film with a non-zero magnetostriction and a high magnetoelastic coupling, such as an iron-nickel alloy, rare earth metals, ferrites, many different alloys and mixtures thereof, as described above. The film is intended to mean a film with a thickness of about 0.01-1000µm, such as 0.01-200µm, 5-100µm, or 0.01-100µm. Also, the thickness of the film may be much less than the width and the  
25 length of the film.

The magnetoelastic material could be used as sensors for changes in environmental properties as long as the magnetoacoustic resonant frequency changes when the environmental properties change. Changes in environmental properties include changes in mass, which is achieved by the binding of a chemical  
30 analyte such as water, a liquid, urine, humidity or moisture, or a bio-analyte or a chemical analyte, such as such as proteins, hormones, microorganisms, e.g. pathogenic and non-patogenic bacteria, viruses, fungi, and parasites, e.g. protozoans; glucose, or bacterial toxins, nutritiolal markers, DNA, RNA, mammalian cells, such as blood cells, e.g. lymphocytes as further described below.

35 According to the invention, a magnetic field is applied to the magnetoelastic film in the absorbent structure. The amplitude of the pulsed magnetic field must be large enough to magnetize the material, e.g. the magnetoelastic film, to a certain amount in order to achieve a sufficiently large change in material dimensions. The specific magnetic fields must therefore be optimised for each magnetostrictive

material chosen.

Further embodiments include where a pulsed magnetic field or a pulsed sinewave magnetic field is applied to the magnetoelastic film in the absorbent structure according to the invention. It will then be possible to detect a characteristic resonant frequency, i.e. the magnetoacoustic effect, between the magnetic pulses.

Different embodiments include where the pulse frequencies are about 10-1000Hz.

Even further embodiments include where the pulse frequencies are about 50-700 Hz.

The duty cycles of the pulses may be about 1-90%. Further embodiments include wherein the duty cycles are 10-50%.

In a specific embodiment, the magnetic field is a pulsed sinewave field. Such sinewaves may be about 50-60 kHz.

In one embodiment using METGLAS<sup>®</sup> material from Honeywell as the magnetoelastic material, a magnetic field amplitude of the pulsing field may be about 0.05-0.1 mT.

Even further embodiments, when using the METGLAS<sup>®</sup> material from Honeywell, may include a magnetic bias field of about 0.5-1 mT.

Further embodiments include wherein the excitation frequency is swept across the resonance frequency to determine a frequency shift and Q-value changes, where  $Q = F/(\Delta F)$ , due to absorption of liquid, humidity or moisture, e.g. urine, or at least one biological and/or at least one chemical analyte, or desorption of surface coating of the magnetoelastic film, such as the METGLAS<sup>®</sup> film.

In a further embodiment, a thin ribbon of a magnetoelastic material is used. The magnetoacoustic resonant frequency for e.g. a thin ribbon of a magnetoelastic material is inversely proportional to the length of the ribbon. Thus, it is possible to achieve different resonant frequencies in one sensing device.

In order to detect changes in the resonant frequency, herein the magnetoacoustic effect, correctly the sensor must be designed to measure correct mass changes. The sensor may then be coated with a polymer or other materials that interact with the wetness, e.g. moisture, liquid or humidity, resulting in a change in the magnetoacoustic oscillations, thus being detectable.

One way of doing this, is by coating the magnetoelastic film with a mass-changing material, or a material that may change its properties, in such a way that it affects the mass of the sensing device. This may be achieved in different ways, e.g., by gaining weight through binding a liquid, or by losing weight by, e.g., dissolving as shown in figure 4d. This process, as well as suitable materials for achieving this, is described in detail in the paragraphs *An absorbent structure with a sensing device sensing wetness* or in *An absorbent structure with a sensing device sensing*

*biological or chemical analytes* below.

*Different sensor embodiments*

Different embodiments of the sensor are contemplated.

- 5 One embodiment comprises a sensor that may be packaged or encapsulated accurately, not to be exposed to, e.g., mechanical pressure that may affect the resonant frequency. In such embodiments, the sensor may be packaged in a way that the wetness, at least one biological and/or at least one chemical analyte found in body waste or body exudates to be detected, can penetrate through the package into
- 10 the magnetoelastic sensor, e.g., via pores, slots or holes, in the package material. Suitable encapsulation include encapsulations in the form of tags such as the commercially available tags from, e.g., Sensomatic, or a similar product. Thus, the encapsulations are designed or chosen in each case by the skilled man in the art to fit a specific embodiment.
- 15 In specific embodiments, mechanical pressure may correlate to the amount of analyte to be detected, e.g. wetness, humidity or moisture, at least one biological and/or at least one chemical analyte. Such embodiments may include wherein the package around the sensor is designed to allow liquid to penetrate into a region where there is an absorbing material, e.g., SAP together with magnetoelastic sensor.
- 20 There may then be a mechanical pressure on the sensor correlating to the amount of, e.g., a liquid, such as urine, at least one biological and/or at least one chemical analyte that prevents or decreases oscillation. Said embodiment is shown in figure 4b.

- In another embodiment, a permanent magnet is included in the sensing device
- 25 as shown in figure 4c. Thus, when the absorbent material swells due to uptake of a liquid, such as urine, humidity or moisture thereof, the absorbing material pushes the permanent magnet closer or away from the magneto elastic sensor which will the change the magnetic field. Such a change of the DC magnetic field on the sensor affects the magnetoacoustic oscillations and correlates to the amount of liquid, such
- 30 as urine, humidity or moisture absorbed.

Further embodiments involving a coating are described in detail below in the paragraph *An absorbent structure with a sensing device sensing wetness*.

- In figure 2 it is illustrated how detection from the magneto acoustic effect may be carried out by using one excitation coil that magnetizes the magnetic
- 35 material and one pick-up coil that detects the response from the material.

In figure 3 the same is shown as in figure 2, but in an experimental set-up for detecting the magneto acoustic effect. In the figure, the outer coil is the excitation coil. The inner coil is the pick up coil positioned around the METGLAS<sup>®</sup> film. The coil in the middle is used to counteract the field from the excitation coil, due to this

experimental set up. The position of the excitation coil and the pick up coil is further described in the paragraph *The hand held unit* below.

In different embodiments according to the invention, said absorbent structure comprises at least one sensing device. Due to the different sizing and shaping of such products, the number of sensing devices may differ according in different  
5    embodiments. Examples may be 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 30, 40, 50 sensing device(s).

The actual position of the sensor may also vary, due to different absorption patterns of body fluids, body waste or body exudates, i.e. urine, faeces, blood,  
10    menstruation blood, fluid matters from wounds and sores, rinsing fluid and saliva. Also, different types of absorbent structures and absorbent articles give rise to different types of absorption patterns, due to the different preferred thicknesses of said absorbent articles and different wetting properties of the specific embodiment, which has to be considered when placing the sensors in the absorbent structures and  
15    absorbent articles.

Different embodiments of the invention shown in the figures and the text below exemplify the invention showing sensors placed in the absorbing product. It will be understood that the invention is not limited to the illustrated or described exemplifying embodiments with regards to the actual number of sensing devices,  
20    and how and the at least one sensing device is positioned.

#### *The hand held unit*

The excitation coil for applying a magnetic field, which may be a pulsed magnetic field or a pulsed sinewave field, and the pick up coil that collects the  
25    produced signal, i.e., the magnetoacoustic effect, may be located in a hand held unit. In one embodiment, the hand held unit comprises both the excitation coil and the pick up coil.

In a further embodiment, the same coil may be used both as excitation coil and pick up coil, i.e. for both excitation and detection.

30    In figure 5, a schematic view of a hand held unit, that may be used to excite the magnetoelastic film, detect the response from the film and present the result for the user, is presented. It contains a signal generator that generates and sends signals to the excitation coil and a detection circuit that receives and detects the signals from the pick-up coil. The presentation unit presents the result for the user in a  
35    proper way. The signal generator is connected to the detection circuit so that the detection circuit "knows" when a signal is sent to the excitation coil. Furthermore, the handheld unit must be designed to minimize the magnetic coupling between the excitation coil and the pick-up coil. The position of the pick-up coil with respect to the excitation coil shall be optimised for maximum signal from the film and minimal

signal due to the magnetic field from the excitation coil. The pick-up coil may be oriented 90 degrees with respect to the excitation coil and positioned in the excitation coil. There may be a signal noise in the pick-up coil due to the magnetic field change in the excitation coil but this is handled by proper signal processing.

- 5        In further embodiments, the excitation coil and the pick up coil may be separated in different units.

*An absorbent structure with a sensing device sensing wetness*

- 10        The absorbent structure described above may, in a specific embodiment, include a magnetoelastic film coated with a wetness sensitive material. The coating may be directly onto the magnetoelastic film, or indirectly having other layers in between the magnetoelastic film and the polymer.

- 15        In specific embodiments, the wetness sensitive material may absorb the wetness, such as urine, and in such cases change the mass of the sensing device, which will increase or decrease the total weight of the sensor. This change in mass will either increase or decrease the resonant frequency, e.g., the magnetoacoustic effect, and is thus measurable and further correlates to the amount of wetness, such as urine, absorbed to the sensing device.

- 20        In figure 4a-f, different embodiments of the sensing device are shown. Figure 4a shows the mechanical oscillations from the Metglas film, which may change differently in different embodiments dependent on how the wetness is detected. The different embodiments are further discussed below in detail.

- 25        Referring to figure 5, the change in mass will be picked up as a change in the magnetoacoustic frequency due to a mass-change in the magnetoelastic film by a pick-up coil, and the signal further detected by a detection circuit that detects the signal from the pick-up coil.

- 30        In figure 4b a further embodiment is shown. This embodiment includes wherein the package around the sensor may be designed allowing liquid to penetrate into a region where there is an absorbing material, e.g. SAP, together with the magnetoelastic sensor as shown in figure 4b. The SAP will then exert a mechanical pressure on the sensor when absorbing liquid, moisture or humidity. The pressure will correlate to the amount of e.g. liquid or moisture, that will completely or partially dampen said oscillation. Thus, a decrease in the magnetoacoustic effect will be detected when the oscillations are dampened.

- 35        Still another embodiment is shown in figure 4c. In this embodiment, the absorbing material, such as SAP, pushes a permanent magnet closer or further away from the magnetoelastic sensor when wet or becoming wet. This will change the magnetic field. Such a change of the DC magnetic field on the sensor affects the magnetoacoustic oscillations. Thus, an increase or decrease in the magnetoacoustic

effect may be detected in the embodiment shown in figure 4c, or a similar embodiment detecting such a change in the oscillation.

In figure 4d, a further embodiment is shown. The magnetoelastic film in figure 4d is coated with a material, eg a low molecular weight compound such as NaCl, that dissolves when exposed to a liquid of moisture as shown in the figure. This may also give rise to a mass change, thus increase the magnetoacoustic resonance frequency.

In figure 4e, an embodiment of the sensing device is shown comprising a bias field coil. Such an embodiment may comprise two electrodes, made of e.g. Cu or Al.

In figure 4f, an embodiment of the sensing device is shown. The magnetoelastic film in figure 4f is coated with a wetness sensitive material that swells when exposed to a liquid of moisture as shown in the figure. This may also give rise to a mass change, thus increase the magnetoacoustic resonance frequency. The wetness sensitive material is selected from the group consisting of linear and hydrophilic polymers or chemically/physically cross-linked swellable polymer gels based on polyvinyl alcohol, polyvinyl pyrrolidone, polyethylene oxide and co-polymers thereof, polyurethane, polyamides, starch and derivatives thereof, cellulose and derivative thereof, polysaccharides, proteins, polyacrylonitrile, acrylate based polymers, and mixtures thereof.

In still another embodiment, sensors comprising magnetoelastic films of different lengths, which will give different resonance frequencies, may be placed at different positions in the product. This will allow for a readout locating the precise position or part of the product that has become wet.

#### *25 An absorbent structure with a sensing device sensing biological or chemical analytes*

The absorbent structure described above may in a further embodiment include a magnetoelastic film, which is directly coated or indirectly coated, i.e. with other layers such as suitable coupling layers in-between, with at least one detector molecule onto the sensing device, thus to be adapted to detect a target biological or chemical analyte in body waste, body exudates or the users/wearers skin.

The term "biological analyte" or "bio-analyte" is herein intended to mean biologically derived material such as an enzyme or sequence of enzymes; an antibody; a membrane receptor protein; DNA, RNA; proteins, peptides, an organelle, a natural or synthetic cell membrane; an intact or partial viable or nonviable bacterial, plant or animal cell; or a piece of plant or mammalian tissues or any other biologically derived molecule. Further examples are given below.

The absorbent structure according to the invention may in further embodiments include at least one sensing device sensing a biological or chemical



analyte(s), which is (are) selected from the group consisting of an enzyme, antibody, nucleic acid, such as DNA or RNA; a protein, such as a soluble protein or a membrane protein; a peptide, such as an oligo peptide or a poly peptide; parts of a cell membrane or capsid, such as a bacterial or a mammalian cell membrane, or a virus capsid; a lipid, a carbohydrate, a lectin, and mixtures thereof.

Further embodiments include, wherein the at least one sensing device targets a biological or chemical analyte selected from the group consisting of pathogenic bacteria, non-pathogenic bacteria, e.g. colonic bacteria, viruses, parasites, bacterial toxins, fungi, enzymes, proteins, peptides, mammalian blood cells, such as human white or red blood cells, hormones, mammalian, including human, blood components, such as blood glucose; urine and its components such as glucose, ketones, urobilinogen, and bilirubin; and mixtures thereof.

Still even further embodiments include wherein the bacteria, pathogenic or not, is selected from the group consisting of *Escherichia coli*, *Salmonella typhi*, *Salmonella paratyphi*, *Salmonella enteritidis*, *Salmonella thyphimurium*, *Salmonella heidelberg*, *Staphylococcus aureus*, *Shigella sonnei*, *Shigella flexneri*, *Shigella boydii*, *Shigella dysenteriae*, *Vibrio cholerae*, *Mycobacterium tuberculosis*, *Yersinia enterocolitica*, *Aeromonas hydrophila*, *Plesmonas shigelloides*, *Campylobacter jejuni*, *Campylobacter coli*, *Bacteroides fragilis*, *Clostridia septicum*, *Clostridia perfringens*, *Clostridia botulinum*, *Clostridia difficile*, and mixtures thereof.

Other embodiments include wherein the sensing device includes sensing of a chemical compound or analyte such as health markers or nutritional markers. Health markers or nutritional markers reflects nutritional status of the wearer.

Nutritional markers include, markers for e.g., metabolic efficiency, nutrient deficiencies, nutrient absorption or malabsorption, food and drink intake, food allergies (e.g., to peanuts), food intolerance (e.g., lactose or gluten intolerance), colonic bacteria ecology (e.g., beneficial bacteria such as bifidobacteria and lactobacillus), and total energy balance.

Health markers may include chemical analytes such as heavy metals (e.g., lead, mercury, etc.), radioactive substances (e.g., caesium, strontium, uranium, etc.) fats, enzymes, endogenous secretions, protein matter (e.g., blood casts), mucous, and micro-organisms, as described above, that may be related to various health issues such as infection, diarrhoea, gastrointestinal distress of disease, or poisoning. Heavy metals, especially in certain developing countries and in older and/or less affluent areas of developed countries, are serious health risks. For example, lead and mercury poisoning may occur upon the ingestion of these heavy metals from environmental sources (e.g., from lead paint, unregulated heavy industries, etc.) and can be fatal. More commonly, low-level poisoning by these and other heavy metals results in retarded intellectual and/or physical development, especially in children,

that may occur over a long time and have lasting effects on the individual.

Other examples of nutritional markers include calcium, vitamins (e.g., thiamine, riboflavin, niacin, biotin, folic acid, pantothenic acid, ascorbic acid, vitamin E, etc.) electrolytes (e.g., sodium, potassium, chlorine, bicarbonate, etc.),  
5 fats, fatty acids (long and short chain), soaps (e.g., calcium palmitate), amino acids, enzymes (e.g., lactose, amylase, lipase, trypsin, etc.), bile acids and salts thereof, steroids, and carbohydrates. For example, calcium malabsorption is important in that it may lead to a long-term bone-mass deficiency.

Example 8-11 demonstrates the use of METGLAS® as a biosensor, e.g. a  
10 biosensing device, using wholly or partially physisorbed detector molecules using e.g. a cationic polymer such as polyethyleneimine (PEI, from e.g. Sigma-Aldrich), a colloidal suspension such as polybead polystyrene (PS) microspheres (from e.g. Scientific Polymer Products), or a hydrophobic polymer such as polystyrene (from e.g. Scientific Polymer Products). The experiments show the use of coated  
15 METGLAS® for detection of bacteria and blood cells, e.g. lymphocytes.

Suitable detector molecules to be attached or coated directly or indirectly onto the sensing device, i.e. onto e.g. a magnetoelastic surface, e.g. a Metglas, i.e. metallic glass, amorphous metallic, thus magnetoelastic, surface, sensing  
20 bioanalytes or chemical analytes may include any biorecognition element and are further exemplified by carbohydrates; antibodies or parts thereof, synthetic antibodies or parts thereof, enzymes, lectins, DNA (deoxyribonucleic acid), RNA (ribonucleic acid), cells, and/or cell membranes or any other molecules with a binding capacity for a defined bioanalyte or chemical analyte.

It is obvious to one skilled in the art that any suitable means of applying the  
25 detector molecule than physisorption onto the Metglas surface will be appropriate for other applications. For example, it may be desirable to chemically bind the detector molecule, directly or indirectly, to the surface using any one of a variety of common crosslinker molecules including but not limited to glutaraldehyde, N-hydroxysuccinimide, carbodimides.

For especially high precision applications it may be desirable to use the  
30 technique of making self-assembled monolayers (SAMS) on the detector surface as a mean for coating detector molecules. SAMS can be made by a number of different techniques which is familiar to those skilled in the art. One preferred method of making a SAM is to first deposit a monolayer of an element such as gold, copper,  
35 silver lead, platinum, or even carbon on the sensing surface of the Metglas film; gold is the most preferred element for use in coating the film.

By immersing the coated Metglas film in a solution of organic molecules containing thiol, dithiol, nitril, carboxylic acid, amine or silane functional groups, a SAM layer will be spontaneously formed on the coated surface. Long chain alkane

or aromatic molecules with thiol functional groups are especially preferred to form stable densely packed monolayers on gold surfaces. It is also possible to form a SAM directly on the Metglas surface without first coating with a monolayer of gold or other elements. Alkane phosphates and phosphonates have been shown to form  
5 SAMS on transition metal oxide surfaces and thus would be suitable for forming SAMS on iron, cobalt or niobium based Metglasses. Other methods known in the art can also be used for forming the SAM.

Once the SAM has been formed the detector molecule can be easily attached to the monolayer by a number of means known in the art. The detector molecule can  
10 be physically absorbed onto the monolayer. The detector can also be covalently attached to the monolayer molecules using a second functional group located on the individual molecules including but not limited to succinimide, amino, carboxyl, aldehyde groups. Finally the detector molecule can be immobilized by use of detector molecules and of monolayer molecules which are both labeled with the  
15 appropriate half of a receptor-ligand pair, the streptavidin-biotin system is especially favored for use in positioning detector molecules on the sensor.

If so desired, the non-binding surfaces of the sensor can be blocked to prevent non-specific binding of the analyte molecule to the surface. Such blocking can be achieved in a number of ways including but not limited to: adsorption of a  
20 globular protein such as albumin or casein onto the surface, or by covalently binding a blocking polymer to non-binding sites of the SAM. Medium or short chain PEG molecules are a preferred blocking agent.

#### *Absorbent articles*

25 The absorbent structure according to the invention may be included in different types of absorbent articles. Different embodiments include wherein the structure forms part of a disposable absorbent article, and wherein said article is an absorbent article such as a diaper, a diaper of pant type, incontinence garment, sanitary napkin, wipe, towel, tissue, bed protector, wound or sore dressing, or  
30 similar product comprising the absorbent structure according to the invention, a fluid permeable top sheet, and an essentially fluid-impermeable bottom sheet.

The absorbent articles are further exemplified below, without limiting the invention.

#### 35 *A diaper*

Figure 6a-c shows different embodiments of the invention, being a diaper comprising the absorbent structure according to the invention, a front-part, a back-part, and a crotch-part between the front and back-parts as well as at least one sensing device 20 at different positions in the diaper.

Moreover, the absorbent structure may have a front and a rear end-part, an intermediate centre part, and an inner top sheet layer placed on a side which is intended to face towards the user/wearer, and an outer top sheet layer placed on the opposite side intended to face away from the user/wearer.

5 The diaper may, in different embodiments, be a diaper wherein the absorbent structure according to the invention comprises about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 sensing device(s) 20.

In one embodiment, one sensing device 20 is included. The placement of such a sensing device 20 may be according to figure 6a. The placement may be  
10 different on other embodiments of a diaper, due to different, e.g., wetting profiles and wetting points of a diaper.

The wetting point is an area of the diaper surface onto where the body liquid or body waste first comes into contact. As will be understood, it is not possible in practice to establish any specific point or area in this regard, although it can be  
15 generally accepted that the body liquid or waste will be delivered to the diaper within a given, limited area thereof. In general, this area is displaced slightly towards the front of the diaper part, in the case of both male and female wearers. Since the dispersion of the liquid in the first absorbent layer, i.e. the acquisition layer, is only slight, it is sufficient for this layer to cover solely the area of the diaper  
20 in which wetting is most likely to occur. Accordingly, such aspects are analysed and considered when placing sensing devices in an absorbent structure, such as the diaper according to the invention.

In a further embodiment, several sensors 20, which may possess different resonance frequencies, are placed in the absorbing structure. The placement may be  
25 in the rear, in the front and on the sides of the diaper, as seen in figure 6b. This may allow for measurements over time, of e.g. wetness in the whole diaper. The placement of sensors on the side may as well additionally indicate leakage or, e.g., liquid or faeces in the crotch part of the diaper.

The placements of the sensors 20 in figure 6a and 6b are only to be  
30 considered as examples, and further embodiments are obvious for the particular use and analysis to be performed. For example, if urine is to be measured, several sensors 20 may be placed in the front of the diaper as shown in figure 6c, thus indicating an urination event.

The diaper illustrated in figure 6a-c is comprised of a liquid-permeable top  
35 sheet 1, for instance, a non-woven or perforated plastic film, a liquid impermeable top sheet 2, for instance, a plastic film or a hydrophobic non-woven material, and an absorbent body 3 enclosed between the two layers 1, 2.

The diaper is intended to embrace the lower part of the wearer's trunk, in the manner of a pair of absorbent underpants. The diaper is provided with a back part 4

which, when the diaper is worn, will be located rearwardly on the wearer, a front part 5, which when the diaper is worn will be located forwardly on the wearer, and a narrower crotch part 6 which extends between the back part 4 and the front part 5 of the diaper and which, when the diaper is worn, is located in the crotch region of the wearer, between the thighs thereof. Fastener tabs 7, 8, are provided on the side edges 9, 10 of the back part 4 extending in the longitudinal direction of the diaper, close to the rear waist edge 11 of said diaper, so as to enable the diaper to be secured in the desired pants-like form. When the diaper is to be used, the fastened tabs 7, 8 are fastened to the outer surface of the front diaper part 5, close to the forward waist edge 12, thereby holding the diaper together around the wearer's waist.

The diaper illustrated in figure 6 also includes prestretched elastic devices 13, 14 which extend over the diaper in a V-shaped pattern, with the apex of the V located on the forward waist edge 12 of the diaper. The elastic devices 13, 14 may consist of any suitable material, such as elastic foam, elastic bands or covered elastic threads. For the sake of convenience, the elastic devices 13, 14 have been shown in a stretched state. However, as soon as the tension is removed, the elastic devices will contract and therewith form elastic leg openings on the diaper.

The absorbent structure 3 is comprised of mutually different layers. Nearest to the liquid permeable top sheet 1 is a thin cellulose fluff-pulp layer 15 of high critical bulk, large pore volume and low liquid-dispersion ability. By critical bulk is meant the bulk at which a cellulose body will neither collapse nor expand when becoming wet. A cellulose fluff-pulp of high critical bulk will retain an open structure of large pore volume even when wet.

Seen in a direction towards the liquid-impermeable top sheet 2, there then follows a first absorbent layer 16, which is comprised of cellulose fluff-pulp of large pore volume, high wet resilience and low liquid-dispersion ability, and a second absorbent layer 17 comprised of cellulose fluff-pulp of low pore volume, low wet resiliency and high liquid-dispersion ability. Both absorbent layers also include superabsorbent material.

The cellulose fluff-pulp layer 15 lying closest to the liquid-permeable top sheet layer 17 has a T-configuration with the cross-member of the T being located at the front diaper part 5. The first absorbent layer 16, on the other hand, has an oval shape and is located generally in the crotch part 6 of the diaper, around the so-called wetting point.

The first receiving layer, i.e. the acquisition layer, in the diaper according to the invention thus functions as a receiving area for discharged body liquid or waste.

CTMP fluff, CF fluff, wadding or foam is suitable for use in the first absorbent layer. SAP may be added in different proportions to this layer as well.

The first absorbent layer 16 may also contain between 2-30 %, such as 2-15 % superabsorbent material calculated on the total dry weight of the layer in that area in which the superabsorbent material is mixed. The superabsorbent may be distributed generally uniformly in the layer, within at least one area or region thereof, and is intended to bind any liquid that remains in the layer, even when the layer has been drained by the second absorbent layer 17, which may be a wicking layer.

As mentioned previously, the superabsorbent material in the first absorbent layer should preferably have a high gel-strength, to retain an open fibre structure even when becoming wet.

The second absorbent layer 17 also contains superabsorbent material, which may be in the form of one or more layers of flakes, fibres, granules, powder or the like. The layer extends either over the whole of the absorbent layer 17 or is restricted to at least one area thereof. This area may, for instance, be slightly larger than the absorbent layer 16 and, similar to said layer, may be limited essentially to the crotch part of the diaper.

The proportion of superabsorbent included in the second absorbent layer 17 will preferably be between 2 and 60%, preferably between 19 and 50%, calculated as a fraction of the total dry weight of the layer.

The super absorbent in the second absorbent layer 17 will preferably have a high gel-strength, i.e., has the ability to swell substantially unaffected by normally occurring pressure forces, so as not to block or impede dispersion of the liquid. Characteristic of these super absorbents is that they have a high degree of cross-linking which renders them more difficult to compress in comparison with a gel that has a lower degree of cross linking.

The fluff pulp in layer 17 of the second absorbent layer may comprise substantially fluff-pulp or some other absorbent material having a high liquid-dispersion capability. Chemically produced fluff-pulps, of cellulose material, generally fulfil this. The final fibres may have a weight of 140-190  $\mu\text{g}/\text{m}$ , a low degree of stiffness and low wet-stability, and a critical bulk beneath 8  $\text{cm}^3/\text{g}$  at 2.5 kPa.

The second layer 17 may also comprise a chosen fluff pulp, such as CTMP-pulp or chemical pulp.

Thus, discharged body fluid or waste is first collected in the first absorbent layer 16, which function as a buffer, or reservoir, this layer being successively drained as the second absorbent layer 17, absorbs and disperses the liquid waste.

It will be understood that the illustrated and described diaper is merely intended to exemplify the invention and shall not be considered to limit the scope of the invention. For instance, the shape of the diaper and its construction in other

respects may be varied. Similarly, the first absorbent layer 16 may fully cover the second absorbent layer. Furthermore, the thin cellulose fluff-pulp layer 15 located nearest to the liquid-permeable top sheet layer 1, may be omitted.

It should also be noted that a diaper, as used herein, is particularly used in conjunction with incontinence, particularly adult incontinence, but that the invention is not limited to this particular use or any particular size or type of diaper implied thereby, but may be any diaper obvious to the person skilled in the art.

In a further embodiment, the diaper product comprising the sensing device detecting wetness 20 is a disposable diaper.

10

*A pants type diaper*

According to the invention, a pants type diaper comprising the absorbent structure according to the invention is disclosed. Such a pants type diaper comprises a front-part, a back-part, a crotch-part between the front and back-parts.

Furthermore, it may comprise at least two side-closure parts which mutually join parts of the side-edges of respective front and back-parts, so that the diaper will present a waist opening and two leg openings. The absorbent structure may have a front and a rear end-part, and an intermediate centre part, an inner top sheet layer placed on a side which is intended to face the towards the user/wearer, and an outer top sheet layer placed on the opposite side intended to face away from the user/wearer.

The pants type diaper according the invention may in specific embodiments be a diaper pant, wherein the absorbent structure according to the invention comprises 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 sensing device(s).

In figure 7a, one sensing device 35 is incorporated in the pants type diaper.

Figure 7c shows still a further embodiment with four sensing devices 35 according to the invention. Sensors may be placed in the pants type diaper as in the diaper described above, or in any other configuration to fit the purpose of the wetness detection of the user.

Figure 7b is a perspective view of a simplified embodiment of a pants type diaper, in an assembled or ready-to-wear state. Figure 7a and c shows the same diaper in an unassembled state but with different numbers of sensing devices placed in the absorbing structure. The pants type diaper has a waist opening 9 between respective end-edges 6, 7 of the front and the back parts, and two leg openings 10, 11 which are surrounded by respective side-edges 8 of the crotch-part. Respective side edges 4 of the front -part are joined to corresponding respective side-edges 5 of the back-part, such that the pants will present two-side closure parts 12, 13 which extend from the waist opening 9 to respective leg openings 10, 11 on respective side of the diaper. The side closures may be obtained with the aid of heat sealing,

ultrasonic welding, gluing or sewing techniques or some other suitable conventional technique.

In figure 7a and c the pants type diaper includes a front-part 1, which is intended to be placed forwardly on the wearer, a back-part 2, which is intended to be placed rearwardly on the wearer, and a crotch part 3 which is located between the front and the back parts 1, 2 and which is intended to be placed between the thighs of the wearer. No precise limits can be drawn between the respective parts and the size relationships can vary. Consequently, the pants type diaper in figure 6 and 7 is only a schematic example. Each of the front and the back parts have two side-edges 4, 5 and one end-edge 6, 7. The crotch part 3 has two side edges 8.

As will be seen in figure 7b, when the pants type diaper is in its assembled or ready-to-wear state, the diaper has a waist opening 9 between respective end-edges 6, 7 of the front and the back-parts, and two leg openings 10, 11 which are surrounded by respective side-edges 8 of the crotch-part. Respective side-edges 4 of the front-part are joined to corresponding respective side-edges 5 of the back-part, such that the pants-type diaper will present two-side closure parts 12, 13 which extend from the waist opening 9 to respectively leg openings 10, 11 on respective side of the diaper.

It will be seen in figure 7a and 7b that the pants type diaper includes an elongated absorbent structure 14 according to the invention, which extends in the longitudinal direction of the diaper and which is enclosed between an inner top sheet layer and an outer top sheet layer 16, with the latter facing towards the viewer of figure 7a and 7b. The inner top sheet layer is placed on that side of the absorbent structure 14 which faces towards the wearer in use and is liquid impermeable and comprises e.g. non-woven material. The fibres may comprise, e.g. polyethylene, polypropylene, polyester or mixtures thereof. They may also be comprised of viscose fibres. It is also conceivable for the inner top sheet layer to comprise a perforated plastic sheet, for instance polyethylene film or the like. The outer top sheet layer, or backing sheet, 16 is liquid-impermeable or at least hydrophobic and may, for instance, comprise a sheet of polyethylene or a non-woven material which has been coated or laminated with polyolefins, for instance, so as to become liquid – impermeable or at least hydrophobic.

The absorbent material in the absorbent structure 14 according to the invention, may essentially be the same as for the diaper article described above.

Another embodiment comprises cellulose fibres. The material may also include other absorbents, such as polymeric hydrocolloidal material, e.g. super-absorbents. The absorbent structure may also comprise non-absorbent material, for instance thermoplastic melt fibres, with the intention of strengthening the absorbent structure. Although the absorbent structure in figure 7a-c has only a single layer it is



understood that the absorbent structure may comprise more than one layer in other embodiments according to the invention.

The absorbent structure is not restricted to the shape illustrated in figure 7a-c and other shapes, such as hourglass shapes or T-shapes, are conceivable.

5 Different embodiments shall not be considered to be restricted to the illustrated exemplified embodiments, since several variations are conceivable within the scope of the claims. Further possible pants type diaper to be used, are described in WO 93/17648, incorporated herein by reference.

Further embodiments include wherein the pants type diaper is disposable.

10

#### *A tampon-like structure*

The invention further comprises an absorbent article such as a tampon-like structure. Such an absorbent article comprises the absorbent structure according to the invention. The tampon-like structure may be suitable for the absorption of blood, 15 such as menstrual blood, or as a wound or sore liquid absorbing tampon-like structure. Also, similar tampon-like structures may be suitable for e.g. absorption of saliva in the oral cavity.

In one embodiment, the structure contains 5-100% cellulose fibres mainly comprising fibres of chemothermomechanically produced pulp (CTMP) and between 20 0-15% superabsorbent material, calculated as a fraction of the total weight of the structure in a dry state. In further embodiments, the tampon like structure comprises the absorbent structure according to the invention comprising 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 sensing device(s).

Figure 8 illustrates an exemplifying embodiment of an absorbent article 25 suitable for the absorption of blood, such as a tampon or similar product comprising an absorbent structure according to the invention comprising one sensing device 39. The tampon comprises an absorbent material, which has been rolled to a cylinder-like form 38. In conjunction with rolling the absorbent material into its cylindrical shape, a string 31 is placed in the centre of the cylinder 38 in a conventional 30 manner, and the cylinder 38 is compressed to the desired thickness and shape in a conventional manner. Prior to being compressed and shaped, the absorbent material will suitably have a density range of 0.4-0.9 g/cm<sup>3</sup> and a weight per unit area of 200-600 g/m<sup>2</sup>.

In a further embodiment, the absorbent article suitable for the absorption of 35 blood comprises an absorbent structure of an air-laid web of cellulose fibres used as an absorbent material. The fibres are compressed into a dry-formed sheet having a first density of about 0.2-1.0 g/cm<sup>3</sup> and wherein the compressed sheets are mechanically softened by a non-cutting method to a second reduced density, which is lower than the original, first density. The sheets may then be then delaminated so

as to form a plurality of partially separated thin fibre layers. Such thin fibre layers exhibits density of about  $0.2\text{-}1.0\text{ g/cm}^3$ . The structure in such an embodiment exhibits a density reduction of, after being softened, up to and including 75% and a weight per unit area of between  $30\text{-}2000\text{ g/m}^2$ .

- 5       The absorbent article suitable for the absorption of blood, such as a tampon or similar product comprises the absorbent structure according to the invention. As such, different numbers of sensing devices are included, as mentioned above. In figure 7, one sensing device is included in the absorbent structure. The sensor in a tampon like structure needs to be placed in the interior of the absorbent structure.

10

#### *A sanitary napkin*

- One embodiment of the invention is a sanitary napkin. The napkin may comprise in a conventional manner an absorbent structure, which is enclosed between a fluid-permeable top sheet, which may comprise perforated plastic film or  
15 like material and which lies proximal to the wearer in use, and a fluid-impermeable bottom sheet. A thin fluid-permeable layer, for instance of non-woven material, may be placed between the absorbent structure and the top sheet. The top sheet and bottom sheet have parts, which protrude beyond the absorbent structure and the sheets are mutually joined at these protruding parts. The bottom sheet is comprised  
20 of a suitable plastic material, for instance polyethylene. It will be understood, however, that other known materials may be used for the top and the bottom sheets within the scope of the invention.

- The absorbent structure may comprise one single layer, or several layers. The single layer may consist of a dry-formed material according to the invention, which  
25 contains from 0-10% superabsorbent material. A suitable density range in the case of the absorbent structure is  $0.6\text{-}0.9\text{ g/cm}^3$ , while a suitable weight per unit area is  $200\text{-}300\text{ g/m}^2$ . When the absorbent structure is comprised of a chemothermomechanically produced pulp (CTMP)-material or some other material having a yellowish or brownish colour, a covering layer of chemical pulp white in colour may  
30 be applied to the top of the absorbent structure.

#### *A sensing absorbent system*

- Also included in the invention is a sensing absorbent system, comprising the absorbent structure according to the invention, optionally being part of the  
35 absorbent articles such as the ones described above, and a hand held unit, comprising an excitation coil generating a magnetic field to magnetize said magnetoelastic film and optionally a pick-up coil that detects the magnetoacoustic resonant frequency.

In a further embodiment, the sensing absorbent system is disposable.

Further embodiments include a signal generator, a detection circuit and a presentation unit, as seen in figure 10.

In one embodiment, said sensing absorbent unit comprises a hand held unit comprising said excitation coil and said pickup coil.

5 In the sensing absorbent unit, the magnetic pulses from the excitation coil must be high enough to sufficiently magnetize the magnetoelastic film so as to enable the pick-up coil to detect the magnetoacoustic signals. This, of course, depends on the distance between the handheld unit and the magnetoelastic film, and to some extent, on the relative orientation between the handheld unit and the  
10 magnetoelastic film and must thus be optimized for the specific combination being used.

In one embodiment, METGLAS<sup>®</sup> film is used as the magnetoelastic film. In this embodiment, a magnetic field amplitude of 0.06 mT at the film is high enough in order to detect magnetoacoustic signals. Magnetic pulses of 1 kHz with a duty  
15 cycle of 20 % was used, but other frequencies and duty cycles may be used. A magnetic field in the range of 0.05 mT to 0.1 mT will create sufficient magnetization in the magnetoelastic film. The exact value depends on the chosen material in the magnetoelastic film, and must thus be optimized for each embodiment. The exact values of the pulse frequency, duty cycle and field  
20 amplitude at the film must, in a similar way, be optimized when the material of the magnetoelastic film and the application of the sensor system are chosen. Also, the distance of the hand held unit must be considered here and the value of the maximum distance between the handheld unit and the magnetoelastic film needs to be defined when optimizing other parameters in the different embodiments. The  
25 minimum distance is at the outer surface of the absorbent article. The detection may be designed to enable the largest covering range about x m, where x is chosen by the user of the nursing personnel/care taker by proper design of the excitation coil and the pick-up coil.

In one embodiment, the detection may be designed to enable the largest  
30 covering range about x m, where x is about 0-10 m, such as about 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m.

In a further embodiment, the detection may be designed to enable the largest covering range about x m, where x is about 0-5 m.

In still a further embodiment, the detection may be designed to enable the  
35 largest covering range about x m, where x is about 0-1 m, such as about 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1 m.

#### *Method for producing an absorbent structure*

Also included in the present invention is a method for producing an absorbent

structure according to the invention, or an absorbent article such as a diaper, a diaper of pant type, incontinence garment, sanitary napkin, wipe, towel, tissue, bed protector, wound or sore dressing, or similar product, comprising the steps of

- a) providing a liquid impermeable backing sheet,
- 5 b) providing at least one wetness sensor, and/or at least one biological analyte sensor and/or at least one chemical analyte sensor,
- c) spraying hot-melt glue onto all or part of the backing sheet,
- d) attaching at least one absorbent structure onto the backing sheet,
- e) providing nonwoven on top of the absorbent structure in c), onto the side
- 10 opposite of the backing sheet, and
- f) stamping the absorbent product from the nonwoven - absorbent structure - backing sheet structure in e) above.

The sensor in b) above may first be attached to the liquid impermeable backing sheet, and then provided at the same time as the backing sheet.

- 15 In another embodiment, the sensor is attached to the backing sheet after the hot-melt glue is sprayed into the backing sheet.

The sensor may also be attached to other parts of the absorbent structure, such as onto, inside or between different absorbent structures in the absorbent product.

20

*Method for detecting wetness, a bio-analyte or a chemical analyte*

According to the invention a method for detecting a chemical analyte, such as wetness or a metal, or a bio-analyte, such as a bacteria or a blood cell, in an absorbent structure according to the invention. The absorbent structure may be incorporated in an absorbent article such as a diaper, a diaper of pant type, incontinence garment, sanitary napkin, wipe, towel, tissue, bed protector, wound or sore dressing, or similar product is contemplated. The method comprises the steps of

- a) providing an absorbent structure according to the invention, or an absorbent article according to the invention,
- 30 b) applying a magnetic field,
- c) exciting the magnetoelastic film in the at least one sensing device in the absorbent structure,
- d) switching the magnetic field off,
- e) recording magnetoacoustic resonant frequency,
- 35 f) optionally repeating step b) to e), and
- g) detecting changes in the magnetoacoustic resonant frequency, so as to detect wetness, at least one biological analyte and/or at least one chemical analyte in the absorbent structure.

The method according to the invention may in further embodiments include a

magnetic field, wherein the field is a pulsed magnetic field.

Further embodiments include wherein said magnetoelastic film excited in c) above is excited by an excitation coil.

5 A further embodiment is wherein the recording in e) above is detected by a pick-up coil.

Even further embodiments include wherein the excitation frequency is swept across the resonance frequency to determine a frequency shift and Q-value changes, where  $Q = F/(\Delta F)$ , due to absorption of liquid, humidity or moisture, e.g. urine, or desorption of surface coating of the magnetoelastic film, such as the Metglas film.

10 Figure 2 shows a schematic drawing of a sensing device to be used in such as method. Figure 3 shows a photograph of the same in an experimental set up.

In another embodiment of the method, the excitation coil and optionally the pick-up coil is in a hand held unit, and wherein the hand held unit is 0.1-2m from the absorbing structure when exciting the magnetoelastic film in c) above and  
15 optionally when recording magnetoacoustic resonant frequency in e) above.

A hand held unit to be used according to the invention is also disclosed to be used in the method according to the invention. A schematic view is presented in figure 4.

20 In a still further embodiment, the sensing absorbent system in the paragraph *A sensing absorbent system* above, may be used in the method above.

## EXAMPLES

### *General*

25 In experiment 1-7, the METGLAS® film and the capsule used was Ultra-Strip III Narrow from Sensomatic.

The capsule also contained a permanent magnet in all experiments except experiments 6 and 7.

30 In experiment 8-11, the used METGLAS® film was Ultra-Strip III Narrow from Sensomatic.

In experiment 8-11, prior to coating step, the METGLAS® film was etched in 1 M  $\text{NH}_4\text{OH}$ , washed with deionized water and acetone and dried. In experiment 8-11, the measurements were made in dry state, i. e. dip and dry.

### 35 *Preparation of the Metglas film*

In all the experiments, the capsule was cut open at the short side and the METGLAS® film was withdrawn from the capsule. The METGLAS® film was then coated in different ways according to different experimental conditions and described in each case below. The coated METGLAS® film was then reinserted

into the capsule. The upper side of the capsule was split open to allow liquid to penetrate the capsule and reach the coating on the METGLAS® film.

The capsule was then wrapped with a surfactant-treated polypropylene nonwoven material. The resulting device (denoted AA) was integrated into the  
5 diaper according to the descriptions below.

#### *The diaper*

In all the experiments, the diaper was composed of

1. Liquid-impermeable casing sheet based on polyethylene (ME 1148 from  
10 Trioplanex International),
2. Cellulose CP fluff pulp (Supersoft Plus from international paper containing 48 g/m<sup>2</sup> of superabsorbent polymer (SAP) Drytech S230R from Dow Chemicals),
3. Cellulose CTMP fluff pulp (SF 70 HD VSM from Metsä Serla containing  
15 73 g/m<sup>2</sup> SAP Drytech S230R from Dow Chemicals),
4. Surfactant-treated nonwoven based on polypropylene (Holmestra Spunbond HO18B7W from Fiberweb Sweden),
5. Hot-melt glue (0700108 from National Starch).

#### *20 Experimental setup*

In experiment 1-7, the setup included an excitation coil of 25 turns and diameter 25 cm and an eight-shaped detection coil of two 25 turn square coils with a side length of 3 cm. The excitation coil was vertically aligned and the detection coil horizontally aligned along the center axis of the excitation coil as shown in figure  
25 11. Referring to figure 11, the diaper was placed in such way that the integrated sensor was positioned on top of the detection coil.

A magnetic field is produced on applying an amplitude modulated sinusoidal current to the excitation coil. The amplitude modulation is square-wave shaped, turning the sinusoidal signal on and off with a frequency around 100 Hz and a duty  
30 cycle of 10-50 percent. The peak-to-peak value of the applied current is approximately 0.1 A, and the frequency, 10 kHz to 100 kHz. The magnetic field causes a magnetoacoustic oscillation in the Metglas film. The oscillation induces a voltage in the detection coil. The amplitude and frequency of the voltage in the detection coil is measured with a spectrum analyzer.

35 In examples 6 and 7, no permanent magnet was present in the capsule. Thus, the experimental design in these experiments was changed to include an extra circular bias coil of 25 turns and a diameter of 25 cm to produce a magnetic bias field and the bias coil was given a current of 2.2 A, thus generating a magnetic field of approximately 200 mT. This bias-field replaces the bias magnet, i.e. the

permanent magnet, used in the other experiments. The bias coil is placed in the same position as the excitation coil.

In example 8-11, the device under test was placed 8 mm above an eight-shaped coil, as shown in figure 24. The eight-shaped coil was constructed by connecting two 25 turn square coils with side length of 3 cm. The eight-shaped coil was used both for excitation and for detection. The eight-shaped coil was connected to a magnetoelastic resonance detection system, containing a signal generator, a detection circuit and a data acquisition unit. The acquired data was exported to a desktop computer where the data was analyzed. The setup also included a Helmholtz coil of 100 turns (each coil) with a diameter of 19.5 cm. The Helmholtz coil was used to produce a homogenous magnetic bias field around the device under test.

A current of 0.9 A was passed through the Helmholtz coil producing a magnetic field of approximately 0.4 mT. To excite the device under test, a magnetic field was generated by passing a sinusoidal current through the eight-shaped coil. The amplitude of the current was approximately 30 mA and the frequency 50 kHz to 60 kHz. The excitation signal was switched off after 5 ms. The oscillation of the device under test induced a voltage in the eight-shaped coil which was detected. The amplitude and the frequency of the induced voltage were analyzed using Matlab<sup>®</sup> software (The MathWorks, Inc.) on a desktop computer. An overview of the experimental set up is seen in figure 25.

#### Example 1 Wet sensor coated with a hydrophilic linear polymer

##### 25 *Objective*

The objective of this example is to analyse wetness in a diaper using a wet sensor coated with a hydrophilic linear polymer.

##### *Materials and methods*

30 The METGLAS<sup>®</sup> film was coated with a 1% (w/w) polyvinylpyrrolidone (PVP) solution.

PVP with a molecular weight of 360 kDa was supplied from Scientific Polymer Products. The Metglas film was dried at 70°C and a PVP-coating was formed on the Metglas-film. The PVP film was thin and weighed in total 0.017g.

35 The sensor was included in the absorbent structure by attaching the AA-device to the liquid impermeable backing sheet 27 cm from the centre front of the liquid impermeable casing sheet.

The absorbent structure was covered with two cellulose fluff pulp materials in the following order; CP followed by CTMP.

Finally, the surfactant-treated nonwoven was placed at the top.

### *Results*

A total amount of 100 ml synthetic urine was added in three aliquots at  
5 different time points; 20 ml at 60 s, 20 ml at 560 s and 60 ml at 1050 s.

The wetting point was located 36 cm below the centre front of the impermeable backing sheet.

The frequency shifted from  $5.93 \times 10^4$  Hz to  $5.75 \times 10^4$  Hz as shown in figure  
13.

### 10 *Conclusions*

The change in frequency shows that the sensor absorbs the synthetic urine. The sensor thereby changes its resonance frequency due to a density shift of the coated Metglas film when absorbing the synthetic urine.

### 15 Example 2 Wet sensor coated with a hydrophilic crosslinked polymer

#### *Objective*

The objective of this example is to analyse wetness in a diaper using a wet sensor coated with a hydrophilic crosslinked polymer.

20

#### *Materials and methods*

The Metglas film was coated with a gel based on slightly crosslinked polyvinyl alcohol (PVOH). The gel was formed by mixing 1 part of 5% (w/w) PVOH-solution with 1.5 parts of 4% (w/w) di-sodium tetraborate decahydrate. The  
25 gel is formed after 5 min of mixing. The gel is then rolled onto the Metglas film and dried in room-climate for at least 12 hours. The dried film weighed in total 0.0011 g.

PVOH had a molecular weight of 125 kDa (supplied from Scientific Polymer Products) and di-sodium tetraborate decahydrate (pro analysi) was supplied from Merck.

30 The product was made by attaching the AA-device to the liquid impermeable backing sheet 27 cm from centre front of the liquid impermeable casing sheet. The absorbent structure was covered with two cellulose fluff pulp materials in the following order; CP and CTMP. Finally the surfactant-treated nonwoven was placed at the top.

35

### *Results*

A total amount of 250 ml synthetic urine was added in five aliquots; 20 ml at 120 s, 20 ml at 600 s, 60 ml at 1200 s, 50 ml 3050 s and 100 ml 4000s.

The wetting point was located 36 cm below the center front of the



impermeable backing sheet. The frequency shifted from  $5.83 \times 10^4$  Hz to  $5.69 \times 10^4$  Hz.

### *Conclusions*

- 5        The change in frequency shows that the sensor absorbs the synthetic urine. The sensor thereby changes its resonance frequency due to a density shift of the coated Metglas film when absorbing the synthetic urine.

### Example 3 Wet sensor coated with a low molecular weight compound

#### 10    *Objective*

The objective of this example is to analyse wetness in a diaper using a wet sensor coated with a low molecular weight compound.

#### *Materials and methods*

- 15        The Metglas film was coated with 12% (w/w) sodium chloride (NaCl) solution.

NaCl (pro analysi) was supplied by Aldrich. The Metglas film was dried at  $70^\circ\text{C}$  and NaCl crystals were formed on the Metglas-film. The NaCl crystals weighed 0.003 g.

- 20        The product was made by attaching the AA-device to the liquid impermeable backing sheet 27 cm from center front of the liquid impermeable casing sheet.

The absorbent structure was covered with two cellulose fluff pulp materials in the following order; CP, and CTMP. Finally the surfactant-treated nonwoven was placed at the top.

25

#### *Results*

A total amount of 100 ml synthetic urine was added in three aliquots; 20 ml at 80 s, 20ml at 305 s and finally 60 ml at 840 s.

- 30        The wetting point was located 36 cm below the center front of the impermeable backing sheet. The frequency shifted from  $5.71 \times 10^4$  Hz to  $5.63 \times 10^4$  Hz.

### *Conclusions*

- 35        The change in frequency shows that the sensor absorbs the synthetic urine. The sensor thereby changes its resonance frequency due to a density shift of the coated Metglas film when the salt is hydrolysed on the Metglas film thereby absorbing the synthetic urine.

#### Example 4 Sensors at different cross-section positions in the absorbent structure

##### *Objective*

The objective of this example is to analyse wetness in a diaper using a wet  
5 sensor coated positioned at different cross-sections in an absorbent structure. The position of the sensor in this experiment should be compared to the sensor position in example 1.

##### *Materials and methods*

10 The Metglas film was coated with 1% (w/w) polyvinylpyrrolidone (PVP) solution.

PVP was supplied from Scientific Polymer Products and had a molecular weight of 360 kDa. The Metglas film was dried at 70°C and a PVP-coating was formed on the Metglas-film. The PVP film was thin and weighed in total 0.017g.

15 The product was made by placing the CP fluff pulp on the liquid impermeable backing sheet. The AA-device was attached to this absorbent structure 27 cm from centre front of the liquid impermeable backing sheet. Compare the position with the position in example 1.

The CTMP absorbent structure was placed above. Finally the surfactant-  
20 treated nonwoven was placed at the top.

##### *Results*

A total amount of 100 ml synthetic urine was added in three aliquots; 20 ml at 80 s, 20 ml at 675 s and 60 ml at 1075 s.

25 The wetting point was located 36 cm below the centre front of the impermeable backing sheet. The frequency shifted from  $5.81 \times 10^4$  Hz to  $5.74 \times 10^4$  Hz.

##### *Conclusions*

30 The change in frequency in this example should be compared to the frequency change in example 1. The two different positions give different changes in the frequency.

Also, due to the different positions, the change in frequency starts at different time points, i.e. after 150 s in example 1 and after about 85 s in example 4.

35 Thus, different positions if the wet sensor in an absorbent structure may be used to monitor the spread of liquid, such as urine, or humidity in the product.

### Example 5 Two sensors placed at different positions in an absorbent structure

#### *Objective*

The objective of this example is to analyse a frequency shift when using two  
5 sensors placed at different positions in an absorbent structure.

#### *Materials and methods*

Two Metglas films were coated with 1% (w/w) polyvinylpyrrolidone (PVP) solution.

10 PVP had a molecular weight of 360 kDa (supplied from Scientific Polymer Products).

The Metglas film was dried at 70°C and a PVP-coating was formed on the Metglas-film. The PVP film was thin and weighed in total 0.017g. One of the Metglas films was cut 3 mm shorter than the other.

15 The product was made by attaching the AA-devices to the liquid impermeable backing sheet 27 cm and 60 cm respectively from the centre front.

The absorbent structure was covered with two cellulose fluff pulp materials in the following order; CP, CTMP. Finally, the surfactant-treated nonwoven was placed at the top.

20

#### *Results*

A total amount of 460 ml synthetic urine was added in seven aliquots; 20 ml at 140 s, 20 ml at 640 s, 60 ml at 1100 s, 60 ml at 2050 s, 100 ml at 2700 s, 100 ml at 3300 s and finally 100 ml at 4600 s.

25 The wetting point was located 36 cm below the centre front of the impermeable backing sheet. The frequency shifted first for the sensor placed 27 cm from center with a change from  $6.36 \times 10^4$  Hz to  $6.26 \times 10^4$  Hz and thereafter for the sensor placed 60 cm from the center front with a change from  $5.74 \times 10^4$  Hz to  $5.64 \times 10^4$  Hz.

30

#### *Conclusions*

This experiment shows a simple and clean way of detecting a frequency shift indicated by two sensors placed in one absorbent structure at two different positions. The different positions of the two sensors led to a kinetic difference of the  
35 frequency change. Such a difference may be used to calculate quantitative changes of the amount of liquid spread in the absorbent structure, when the wetting profile of a specific absorbent structure is known.

### Example 6 Sensors without encapsulation of the Metglas film

#### *Objective*

The objective of this example is to analyse a frequency shift when using a  
5 sensor without encapsulation of the Metglas film.

#### *Materials and methods*

The Metglas film was coated with a gel based on partially crosslinked  
polyvinylalcohol PVOH. The gel was formed by mixing 1 part of 5% (w/w) PVOH-  
10 solution with 1.5 parts of 4% (w/w) di-sodium tetraborate decahydrate. The gel was  
formed after 5 min of mixing. The gel was rolled onto the Metglas film and dried in  
room temperature for at least 12 hours. The dried film weighed in total 0.0039 g.

PVOH was purchased from Scientific Polymer Products and had a molecular  
weight of 125 kDa and di-sodium tetraborate decahydrate (pro analysi) was supplied  
15 from Merck.

The product was made by placing the CP fluff pulp the liquid impermeable  
backing sheet. The coated Metglas film was placed without a capsule onto the  
absorbent structure 41 cm from the centre front of the liquid impermeable backing  
sheet.

20 The CTMP absorbent structure was placed above. Finally, surfactant-treated  
nonwoven was placed at the top.

#### *Results*

A total amount of 170 ml synthetic urine was added in five aliquots;  
25 20 ml at 190s, 20 ml at 570s, 20 ml at 1300 s, 40 ml at 1980s and finally 50 ml at  
3350s. The wetting point was located 36 cm below the centre front of the  
impermeable backing sheet. The frequency shifted from  $5.76 \times 10^4$  Hz to  $5.66 \times 10^4$   
Hz.

#### 30 *Conclusions*

The change in frequency shows that the wet sensor also works without  
encapsulation.

### Example 7 Sensors without a permanent magnet

35

#### *Objective*

The objective of this example is to analyse a frequency shift when using a  
sensor without a permanent magnet.

The frequency shifted from  $6.00 \times 10^4$  Hz to  $5.95 \times 10^4$  Hz.

### *Material and methods*

The Metglas film was coated with 1% (w/w) polyvinylpyrrolidone (PVP) solution.

- 5 PVP was supplied from Scientific Polymer Products and had a molecular weight of 360 kDa. The Metglas film was dried at 70°C and a PVP-coating was formed on the Metglas-film. The PVP film was thin and weighed in total 0.017g.

- The device AA was changed compared to the general description for the other experiments. The permanent magnet was dismantled from the capsule thereby  
10 forming the device named "AA".

The product was made by attaching the "AA"-device to the liquid impermeable backing sheet 27 cm from centre front of liquid impermeable casing sheet.

- The absorbent structure was covered with two cellulose fluff pulp materials  
15 in the following order; CP, and CTMP. Finally the surfactant-treated nonwoven was placed at the top.

### *Results*

- A total amount of 200 ml synthetic urine was added in four aliquots;  
20 20 ml at 70 s, 20 ml at 450 s, 60 ml at 1100 s and finally 100 ml at 2000 s.

The wetting point was located 36 cm below the centre front of the impermeable backing sheet. The frequency shifted from  $6.00 \times 10^4$  Hz to  $5.95 \times 10^4$  Hz.

- 25 Example 8 Biosensor for detection of Staphylococcus aureus using Metglas coated with a cationic polymer

### *Objective*

- The objective of this example is to detect the pathogen *S.aureus* in a target  
30 solution using a biosensor based on Metglas coated with a cationic polymer and primary antibodies.

### *Materials and methods*

- Polyethyleneimine, PEI, a high molecular weight water free polymer and  
35 Glutaraldehyde sol 50% in water were purchased from Sigma-Aldrich; Mouse monoclonal antibody to *S.aureus* peptidoglycan was purchased from Abcam Limited; CCUG 10778 *S.aureus* was purchased from University of Gothenburg, Department of Clinical Bacteriology;

The Metglas film was coated with PEI by dip coating in a 0,5 % (w/w)

PEI/methanol solution. The Metglas was removed from the coating solution and air-dried to allow solvent evaporation. Chemical cross-linking was carried out by exposing the thin polymer layer to the vapors of a 5% (v/v)

Glutaraldehyde/phosphate buffer saline solution (pH 7,0) for 2 h at room  
5 temperature. The Metglas was removed from the glutaraldehyde environment and placed in a heating oven at 100°C for 4 minutes.

Finally, the monoclonal antibody (mAb) was immobilized onto the coated surface of the sensor. 200 µl mAb solution (1,4 mg/ml) was added on the polymer layer and incubated at room temperature for 1 h. After the incubation step, the mAb  
10 solution was removed; the surface was washed with PBS pH 7,2 and air-dried.

*S.aureus* was growth in TSB medium at 37°C overnight. The bacterial suspension was centrifuged, the supernatant was discarded and the bacterium resuspended in 0,9% NaCl.

#### 15 *Measurement procedure*

The frequency for the dry biosensor was first determined, and then the biosensor was immersed in 3 ml bacterial suspension for 58 minutes at room temperature. The sensor was removed from the suspension, air-dried and the new frequency was measured.

20

#### *Results*

As seen in Figure 20, measurement 1 gave the frequency (f) 58680 Hz and measurement 2 gave f 58480 Hz.

The  $\Delta f$  is 200 Hz.

25

#### *Conclusion*

The frequency shift indicates binding of the target species to the biosensor.

The change in frequency shows the response of the sensor to additional surface mass load.

30

#### Example 9 Biosensor for detection of *Staphylococcus aureus* using Metglas coated with a colloidal suspension

#### 35 *Objective*

The objective of this example is to detect the pathogen *S.aureus* in a target solution using a biosensor based on Metglas coated with a polystyrene bead and primary antibodies.

### *Materials and methods*

Polybead Polystyrene (PS) microspheres (2,65% solids-latex,  $\theta$  1  $\mu$ ) was purchased from Scientific Polymer Products; Mouse monoclonal antibody to *S.aureus* peptidoglycan was purchased from Abcam Limited; CCUG 10778

- 5 *S.aureus* was purchased from University of Gothenburg, Department of Clinical Bacteriology. The Metglas film was coated with PS microspheres by dip coating in a 2,5 % Ps-latex colloidal suspension. The Metglas was immersed in 2 ml coating solution for 30 minutes at room temperature. The Metglas was removed from the coating suspension and placed in a heating oven at 50°C for 15 minutes. Finally, the
- 10 monoclonal Ab was immobilized onto the coated surface of the sensor.

The coated Metglas was immersed in 400  $\mu$ l Ab solution (1,4 mg/ml) and incubated at room temperature for 1 h. After the incubation step, the Ab solution was removed and the sensor was air dried at room temperature.

- S.aureus* was growth in TSB medium at 37°C overnight. The bacterial
- 15 suspension was centrifuged, the supernatant was discarded and the bacterium resuspended in 0,9% NaCl.

### *Measurement procedure*

- First, the frequency for the dry biosensor was determined, and then the
- 20 biosensor was immersed in 3 ml bacterial suspension for 45 minutes at room temperature. The sensor was removed from the suspension, air-dried and the new frequency was measured.

### *Results*

- 25 As seen in Figure 21, measurement 1 gave f 58140 Hz and measurement 2 gave f 57980 Hz.

The  $\Delta f$  is 160 Hz.

### *Conclusion*

- 30 The change in frequency shows the response of the sensor to additional surface mass load. The frequency shift indicates binding of the target species to the biosensor.

Example 10 Biosensor for detection of *Staphylococcus aureus* using Metglas coated with a hydrophobic polymer

*Objective*

- 5       The objective of this example is to detect the pathogen *S.aureus* in a target solution using a biosensor based on metglas coated with a hydrophobic polymer and primary antibodies.

*Materials and methods*

- 10       Polystyrene with a molecular weight of 45 kDa was purchased from Scientific Polymer Products; Mouse monoclonal antibody to *S.aureus* peptidoglycan, was purchased from Abcam Limited; CCUG 10778 *S.aureus* was purchased from University of Gothenburg, Department of Clinical Bacteriology.

- 15       The Metglas film was coated with polystyrene (PS) by dip coating in a 1% (w/w) PS/toluene solution. The Metglas was removed from the coating solution and air-dried to allow solvent evaporation. The Metglas was placed in a heating oven at 100°C for 4 minutes.

- 20       Finally, the monoclonal Ab was immobilized onto the coated surface of the sensor. 200 µl stock solution of mAb (1,4 mg/ml) was added on the polymer layer and incubated at room temperature for 1 h. After the incubation step, the Ab solution was removed; the surface was washed with PBS pH 7,2 and air-dried.

*S.aureus* was growth in TSB medium at 37°C overnight. The bacterial suspension was centrifuged, the supernatant was discarded and the bacterium resuspended in 0,9% NaCl.

25

*Measurement procedure*

- 30       First, the frequency for the dry biosensor was determined, and then the biosensor was immersed in 3 ml bacterial suspension for 58 minutes at room temperature. The sensor was removed from the suspension and air-dried and the new frequency was measured.

*Results*

As seen in Figure 22, measurement 1 gave f 57899 Hz and measurement 2 gave f 58060 Hz.

- 35       The  $\Delta f$  is -60 Hz.

*Conclusion*

The results show a reverse response after immersion of biosensor in the target solution. At excitation of the sensor, a more flexible binding may cause



orientation of the complex away from the surface of the sensor. This phenomenon may give rise to different oscillation direction, i.e. the oscillation of Ab-Ag complex is not in phase with the oscillation of sensor and this may explain the reverse response of the sensor.

- 5        A reverse response may also be obtained if the surface of the sensor becomes more rigid due to the binding of the target molecules

Example 11 Biosensor for detection of Lymphocytes using Metglas coated with a cationic polymer

10

*Objective*

The objective of this example is to detect lymphocytes present in a target solution using a biosensor based on Metglas coated with a cationic polymer and primary antibodies.

15

*Materials and methods*

- Polyethyleneimine, PEI, a high molecular weight water free polymer and Glutaraldehyde sol 50% in water were purchased from Sigma-Aldrich; Mouse anti - ovine B and activated T cells was purchased from Serotec; Sheep blood was  
20 purchased from Statens Veterinärmedicinska Anstalt; Ficoll 400, Sodium diatrizoate and Balanced Salt Solution (BSS) were purchased from Sigma-Aldrich.

- The Metglas film was coated with PEI by dip coating in a 0,5 % (w/w) PEI/methanol solution. The Metglas was removed from the coating solution and air-dried to allow solvent evaporation. Chemical cross-linking was carried out by dip  
25 coating in a 2,5 % (v/v) Glutaraldehyde/phosphate buffer saline solution, PBS, (pH 7,0) for 30 min at room temperature. The Metglas was removed from the glutaraldehyde environment and placed in a heating oven at 100°C for 4 minutes.

- Finally, the monoclonal antibody (mAb) was immobilized onto the coated surface of the sensor. 200 µl stock solution of mAb (as received from Serotac) was  
30 added on the polymer layer and incubated at room temperature for 1 h. After the incubation step, the mAb solution was removed; the surface was washed with PBS pH 7,2 and air-dried.

- Isolation of lymphocytes from whole sheep blood was carried out by density gradient separation technique. The separation medium containing ficoll and sodium  
35 diatrizoate has a density of 1.077 g/ml at room temperature. BSS (25 ml) was added to a centrifuge tube (50 ml) containing whole sheep blood (25 ml). After mixing by inverting of the tube, 25 ml of the blood sample was carefully layered onto 15 ml separation medium and centrifugation was performed at room temperature. The

lymphocyte layer was carefully collected, washed with sterile PBS (2x) and resuspended in PBS (2,5 ml).

*Measurement procedure*

- 5        First, the frequency for the dry biosensor was determined, and then the biosensor was immersed in 2,5 ml lymphocyte suspension for 30 minutes at room temperature. The sensor was removed from the suspension, air-dried and the new frequency was measured.

10    *Results*

As seen in Figure 23, measurement 1 gave  $f$  58665 Hz and measurement 2 gave  $f$  58428 Hz.

The  $\Delta f$  is 237 Hz.

15    *Conclusion*

The frequency shift indicates binding of the target species to the biosensor.

The change in frequency shows the response of the sensor to additional surface mass load.

20

25

## CLAIMS

1. An absorbent structure, comprising at least one absorbent layer and at least one sensing device comprising a magnetoelastic film.  
5
2. The absorbent structure according to claim 1, wherein the least one absorbent layer comprises 0-100% of superabsorbent material.
3. The absorbent structure according to any of claims 1-2, wherein the at least one absorbent layer form at least one acquisition layer, and at least one storage layer.  
10
4. The absorbent structure according to any of claims 1-2, wherein the at least one absorbent layer comprise at least one drying layer, and wherein the layers optionally comprises a plurality of individual sheets and bonding means for joining said individual sheets.  
15
5. The absorbent structure according to any of claims 1-4, wherein the magnetoelastic film is oscillating with a magnetoacoustic resonant frequency, after the magnetoelastic film is excited in a magnetic field and when the magnetic field is switched off.  
20
6. The absorbent structure according to any of claims 1-5, wherein the at least one sensing device is 1-20 sensing device(s).  
25
7. The absorbent structure according to any of claims 1-6, wherein the magnetoelastic film is a thin film, and wherein the film is selected from the group consisting of magnetostrictive material, such as magnetoelastic material, soft magnetoelastic material, amorphous magnetoelastic material, and mixtures thereof.  
30
8. The absorbent structure according to any of claims 1-7, wherein the magnetoelastic film is coated with a wetness sensitive polymer selected from the group consisting of linear and hydrophilic polymers or chemically/physically cross-linked swellable polymer gels based on polyvinyl alcohol, polyvinyl pyrrolidone, polyethylene oxide and co-polymers thereof, polyurethane, polyamides, starch and derivatives thereof, cellulose and derivative thereof, polysaccharides, proteins, polyacrylonitrile, acrylate based polymers, and mixtures thereof.  
35

- 5           9. The a absorbent structure according to any of claims 1-7, wherein the  
          magnetoelastic film is coated directly or indirectly with at least one  
          detector molecule adapted to detect at least one target biological and/or  
          chemical analytes.
- 10          10. An absorbent article such as a diaper, a diaper of pant type, incontinence  
          garment, sanitary napkin, wipe, towel, tissue, bed protector, wound or  
          sore dressing, or similar product comprising the absorbent structure  
          according to any of claims 1-9, a fluid permeable, and an essentially fluid-  
          impermeable bottom sheet.
- 15          11. A diaper and a pant type diaper, comprising the absorbent structure  
          according to any of claims 1-9, a front-part, a back-part, a crotch-part  
          between the front and back-parts.
12. The diaper according to claim 11, wherein the absorbent structure  
          according to any of claims 1-9 comprises 1-10 sensing device(s).
- 20          13. An absorbent article, such as a tampon like product, comprising the  
          absorbent structure according to any of claims 1-9.
- 25          14. The absorbent article according to claim 13, wherein the absorbent  
          structure comprises 5-100% cellulose fibres, mainly comprised of fibres  
          of chemothermomechanically-produced pulp, and between 0-95% super-  
          absorbent material, calculated on the total weight of the structure in a dry  
          state.
- 30          15. A sensing absorbent system, comprising the absorbent structure  
          according to any of claims 1-9, optionally being part of the absorbent  
          articles according to any of claims 10-14, and a hand held unit,  
          comprising an excitation coil generating a magnetic field to magnetize  
          said magnetoelastic film and optionally a pick-up coil that detects the  
          magnetoacoustic resonant frequency.
- 35          16. The sensing absorbent system according to claim 15, wherein the hand  
          held unit comprises the excitation coil and the pickup coil.
17. A method for detecting wetness, and/or at least one biological and/or at

least one chemical analyte in an absorbent structure according to any of claims 1-9, an absorbent article according to any of claims 10-14, or the system according to claim 15-16, comprising the steps of

- 5           a) providing an absorbent structure according to any of claims 1-9, an absorbent article according to any of claims 10-14, or the system according to claim 15-16,
- b) applying a magnetic field,
- c) exciting the magnetoelastic film in the at least one sensing device in the absorbent structure,
- 10          d) switching the magnetic field off,
- e) recording magnetoacoustic resonant frequency,
- f) optionally repeating step b) to e), and
- g) detecting changes in the magnetoacoustic resonant frequency, so as to detect wetness/moisture/humidity, and/or at least one biological
- 15          and/or at least one chemical analyte in the absorbent structure.
18. The method according to claim 17, wherein the magnetic field is a pulsed magnetic field.
- 20          19. The method according to any of claims 17-18, wherein the magnetoelastic film excited in c) above is excited by an excitation coil.
20. The method according to any of claims 17-19, wherein the recording in e) above is detected by a pick-up coil.
- 25          21. The method according to any of claims 17-20, wherein the excitation coil and optionally the pick-up coil is in a hand held unit, and wherein the hand held unit is 0-5 m from the absorbing structure when exciting the magnetoelastic film in c) above and optionally when recording
- 30          magnetoacoustic resonant frequency in e) above.

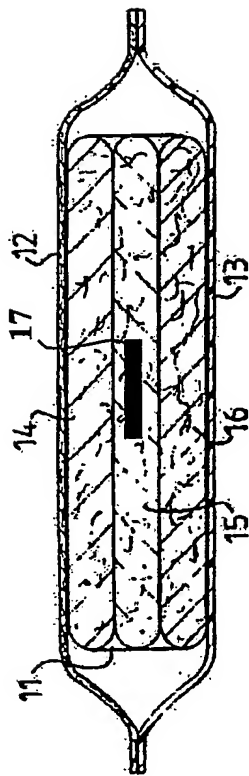


Figure 1A/25

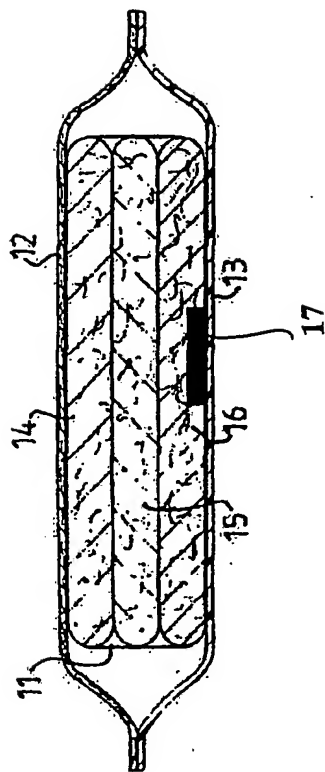
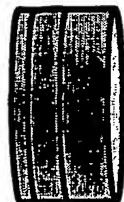


Figure 1B/25

**Excitation coil**



**Pick-up coil**



**Magnetoelastic film**

Figure 2/25



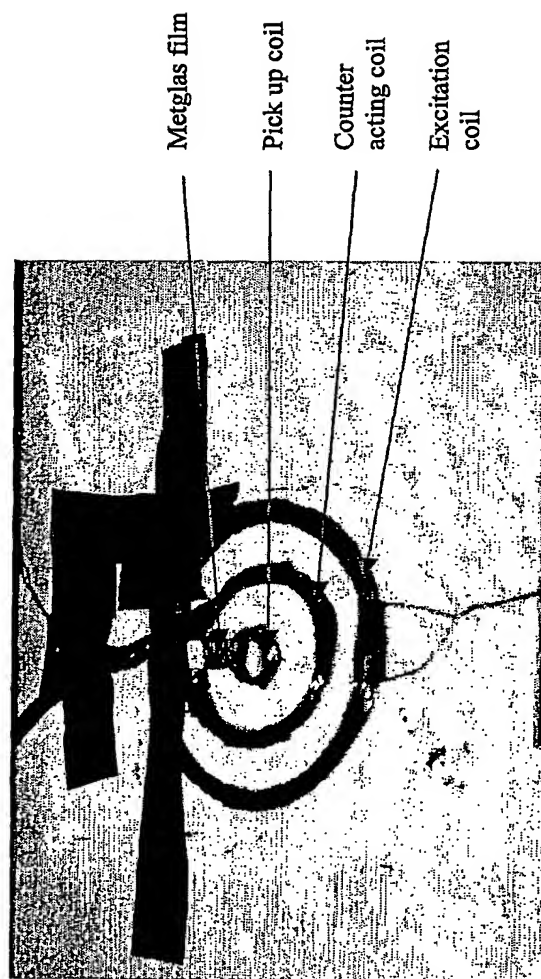


Figure 3/25

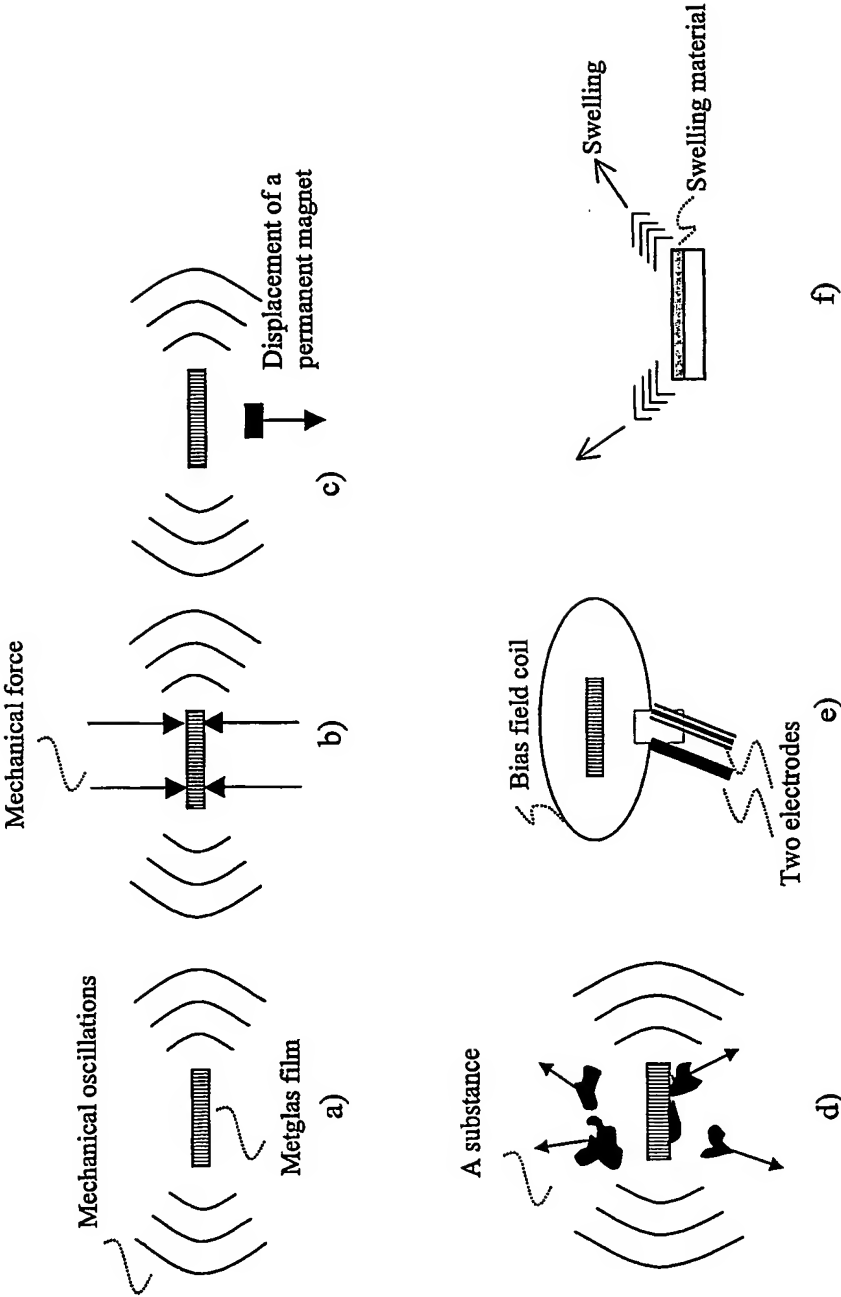


Figure 4/25

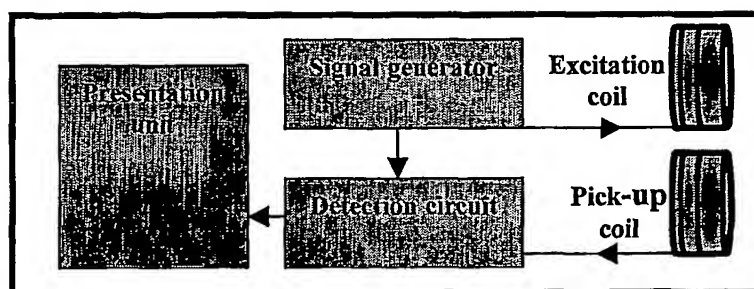


Figure 5/25

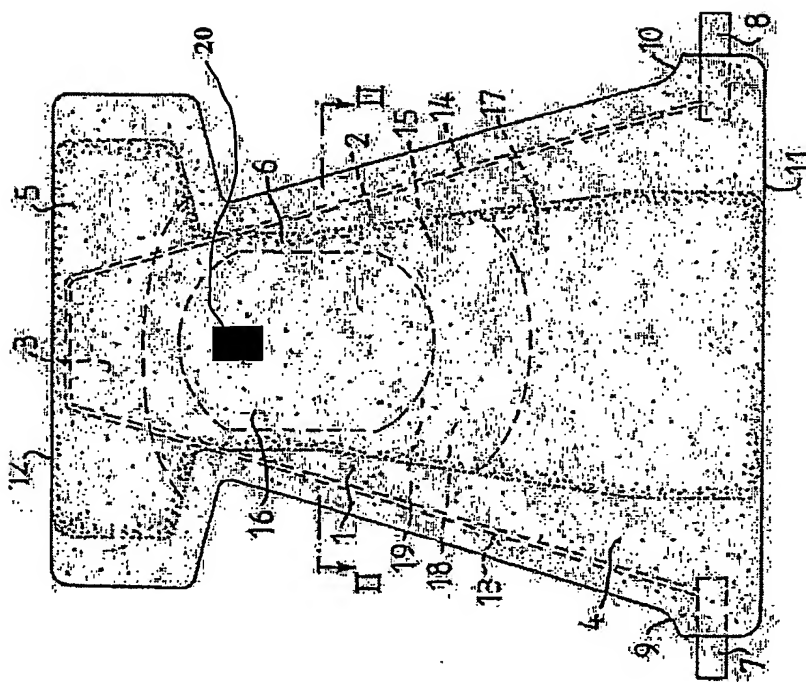


Figure 6A/25

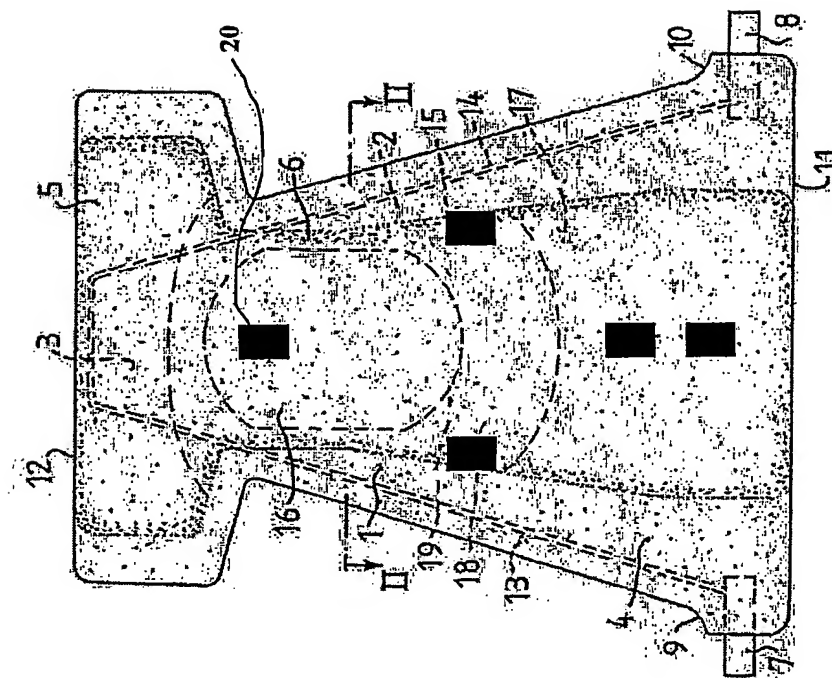


Figure 6B/25

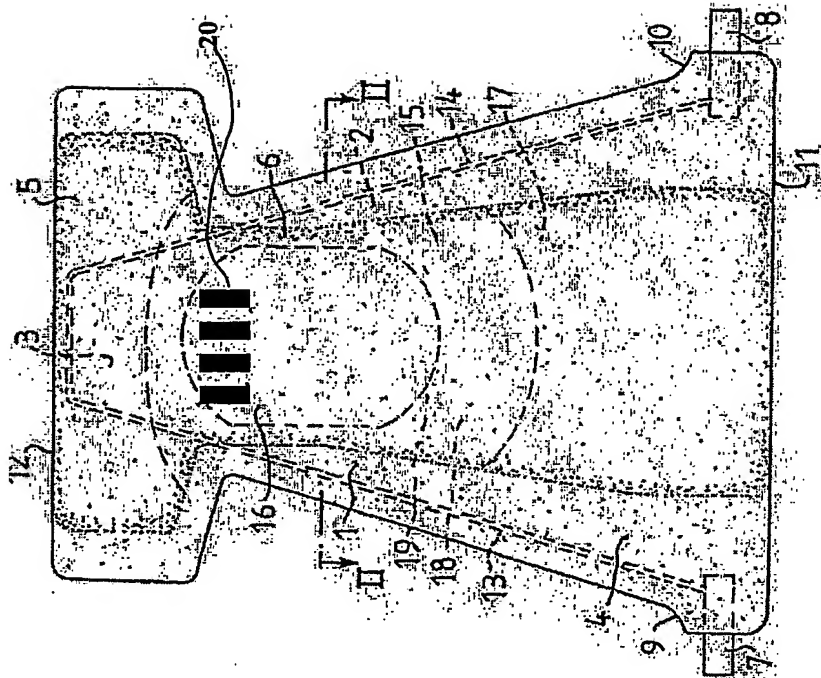


Figure 6C/25

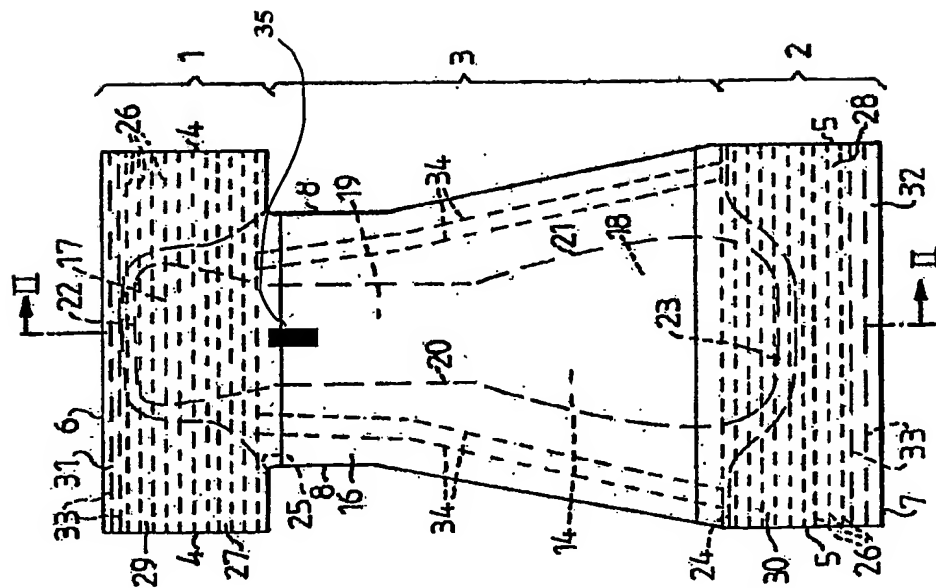


Figure 7A/25

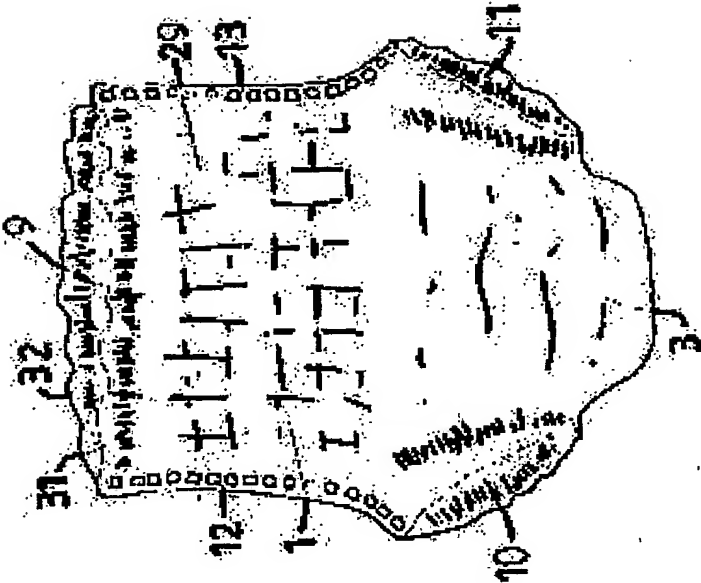


Figure 7B/25



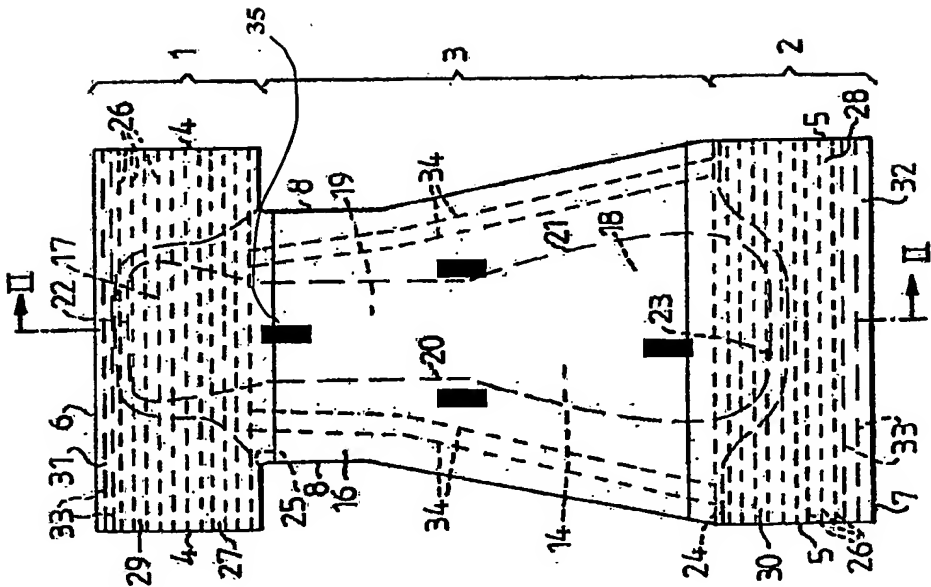


Figure 7C/25

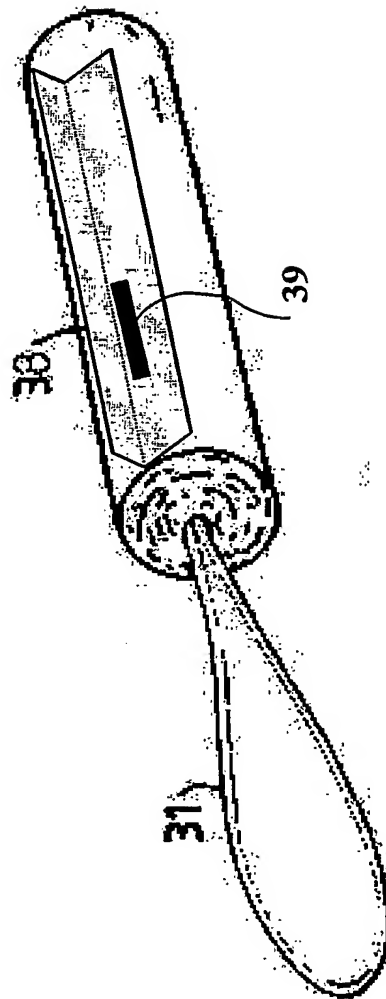


Figure 8/25

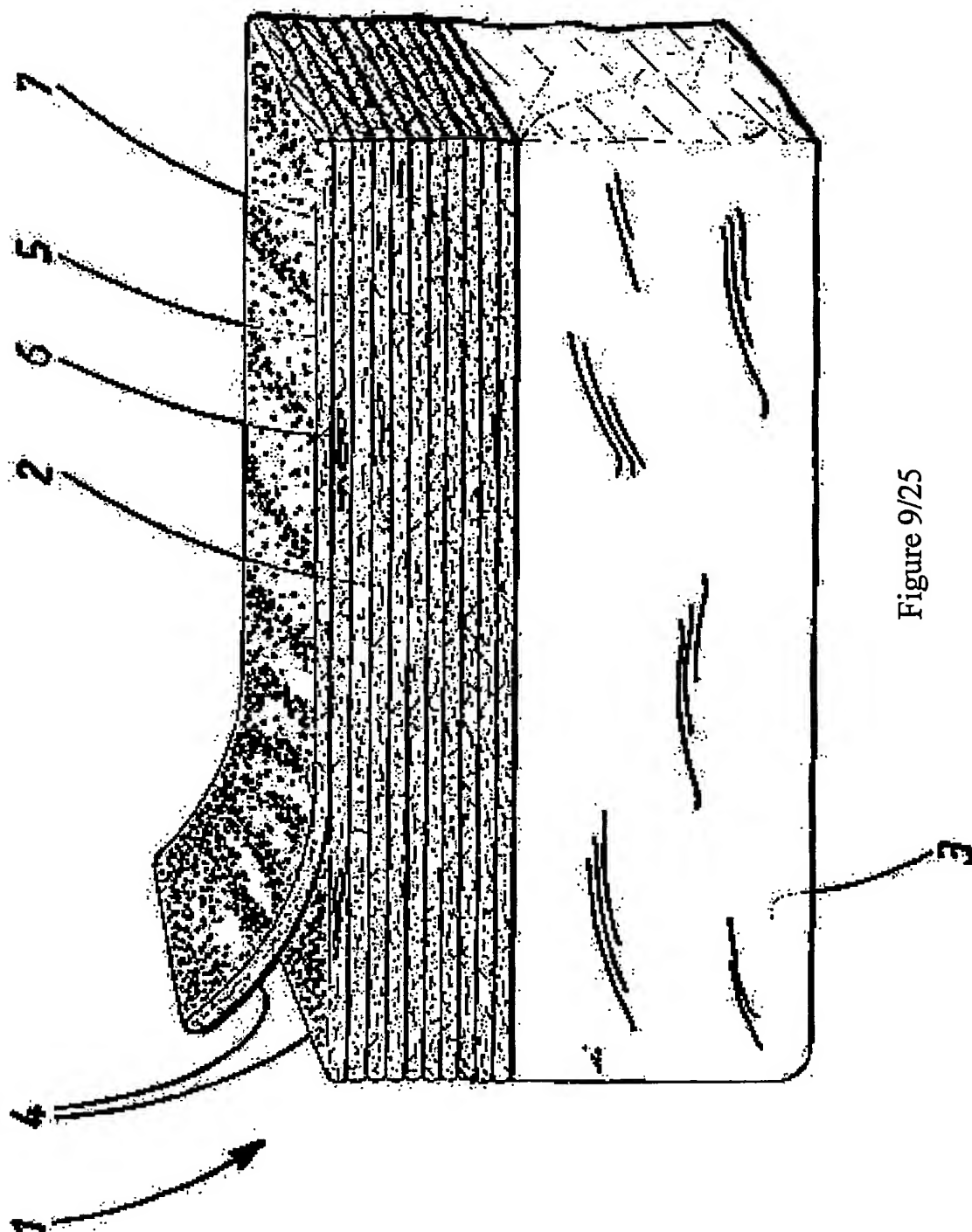


Figure 9/25

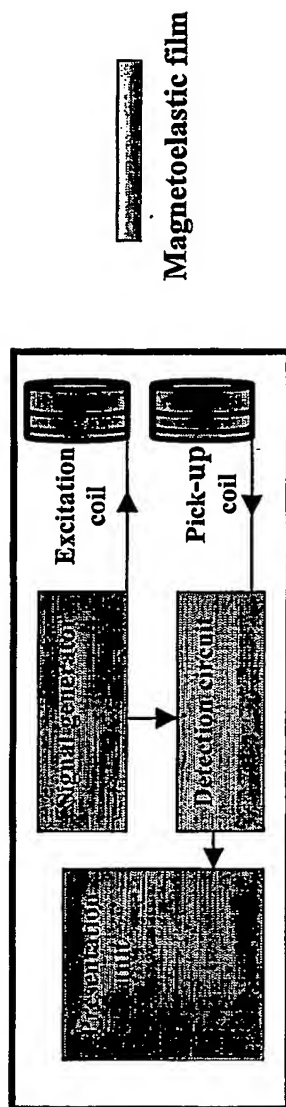


Figure 10/25

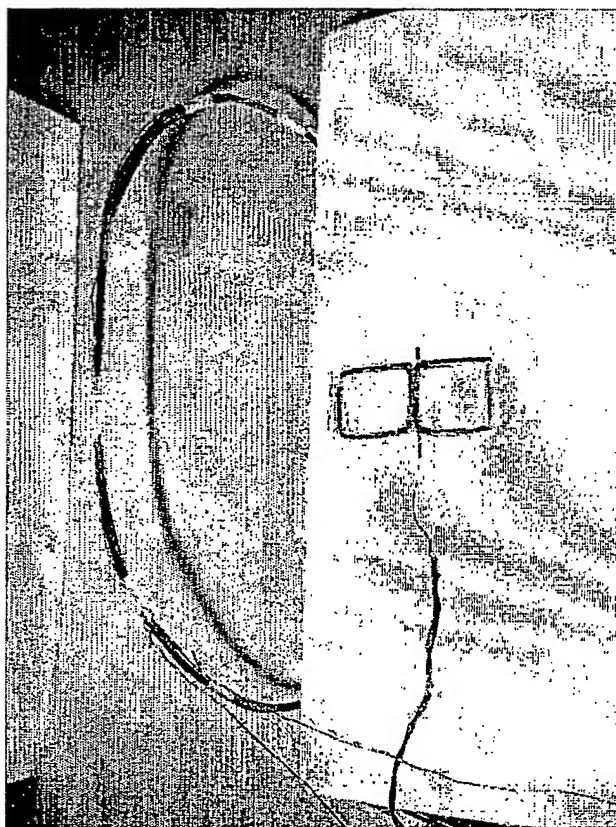


Figure 11/25

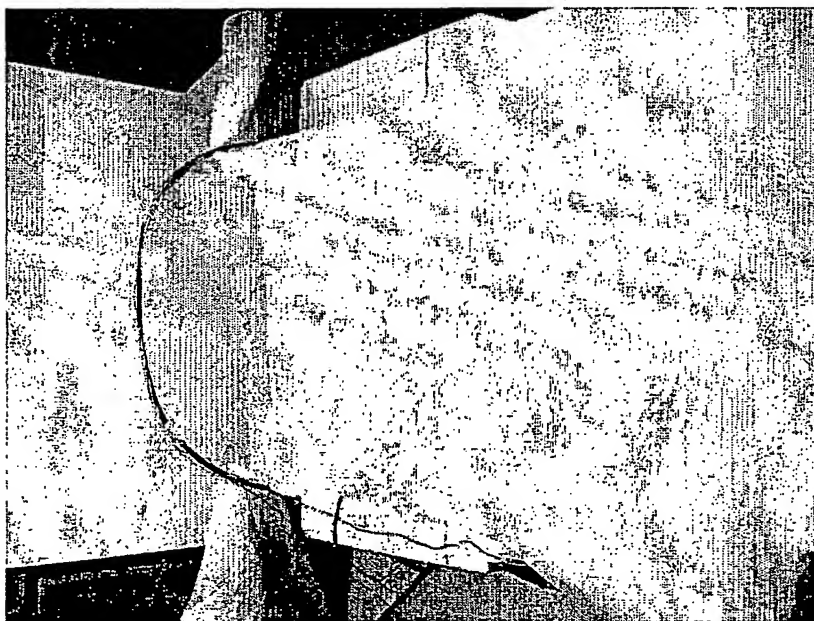


Figure 12/25

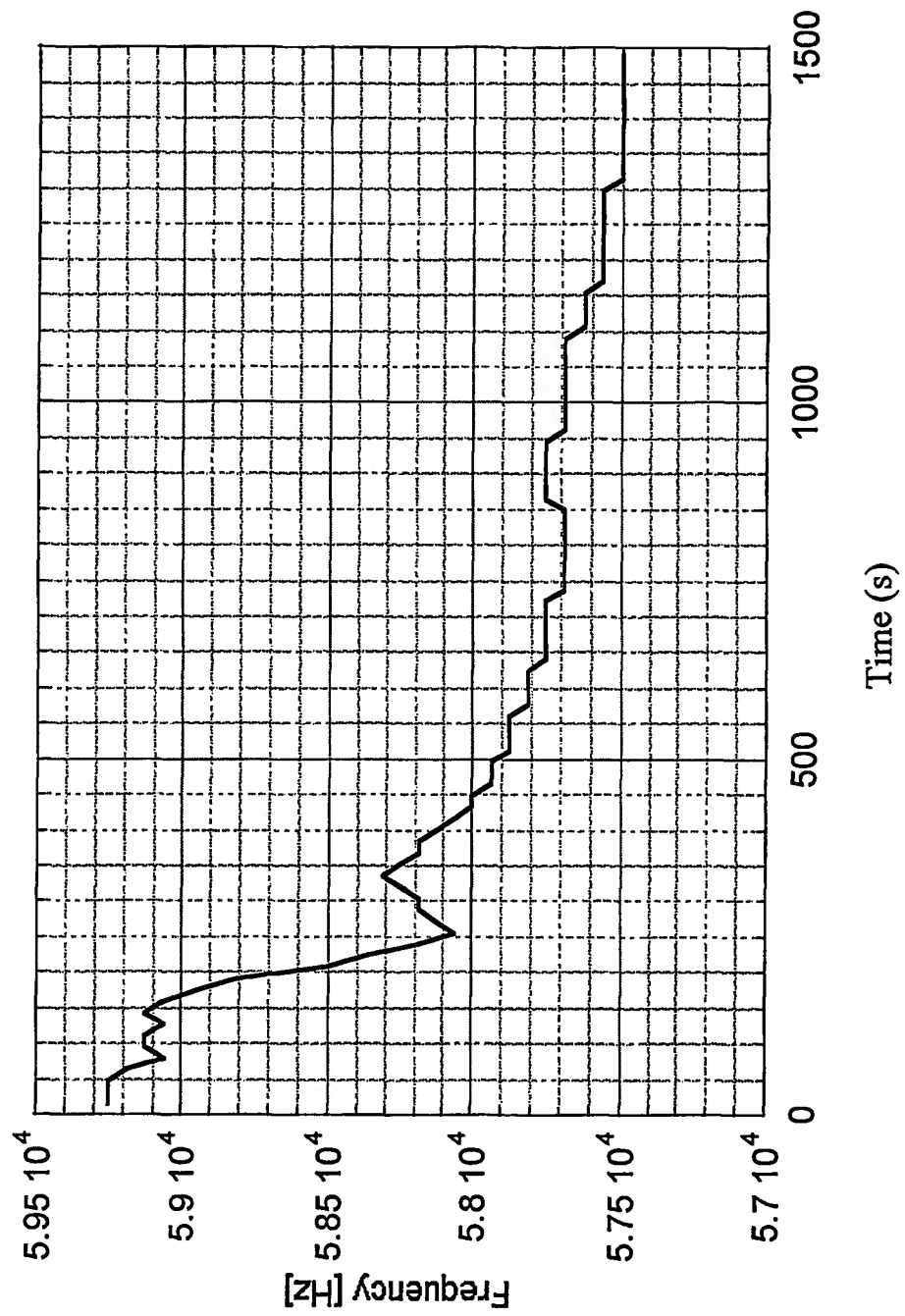


Figure 13/25

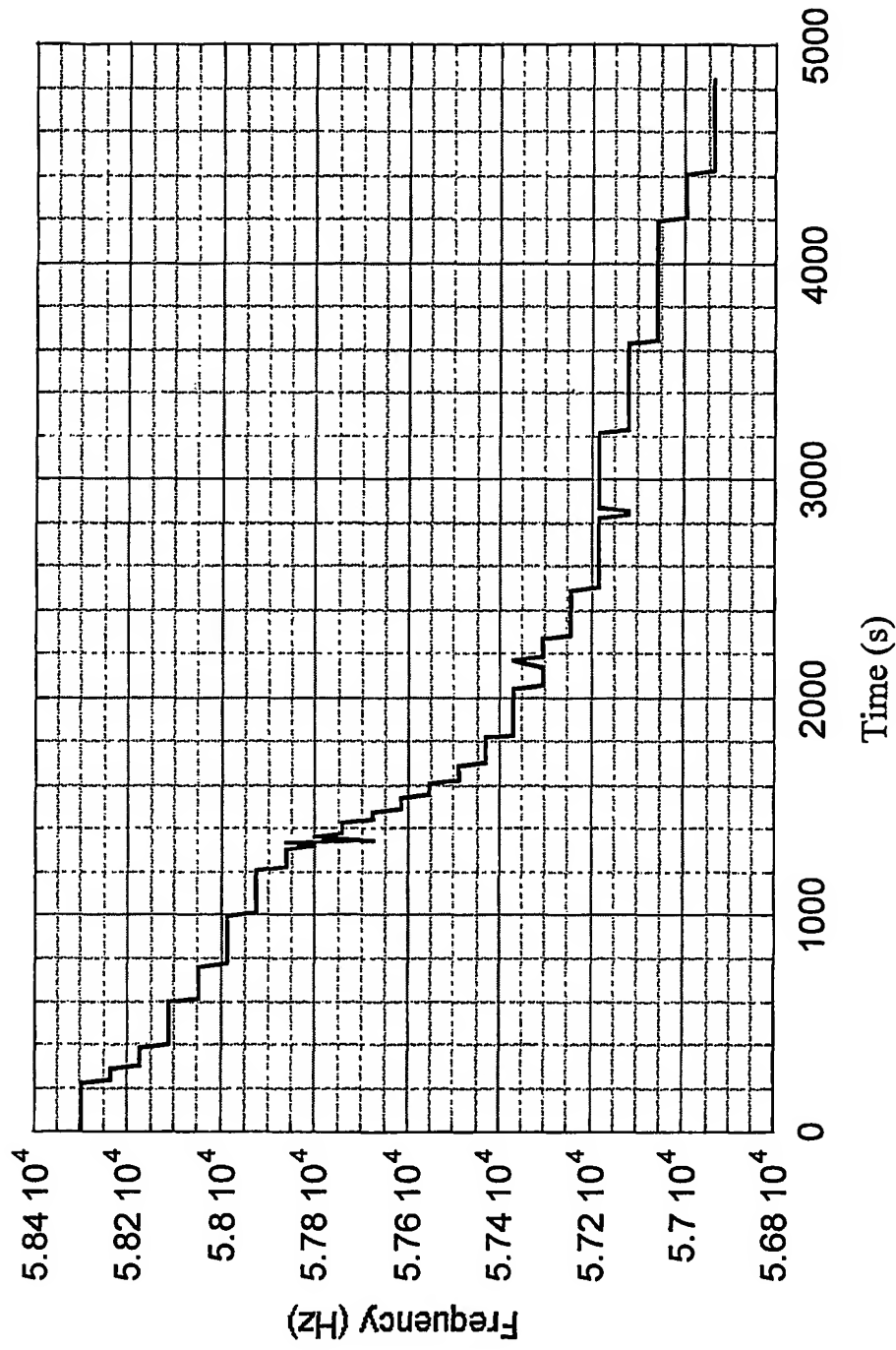


Figure 14/25



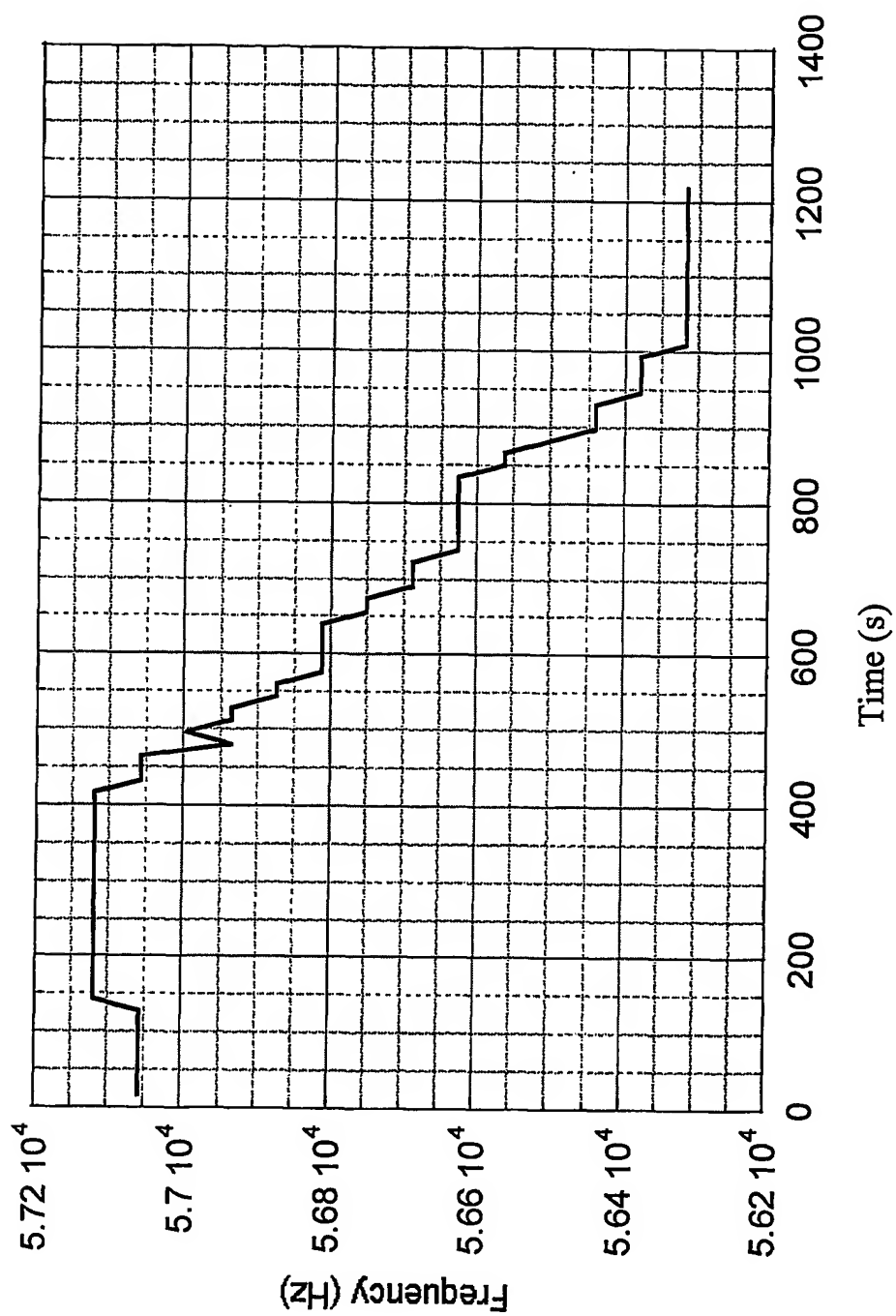


Figure 15/25

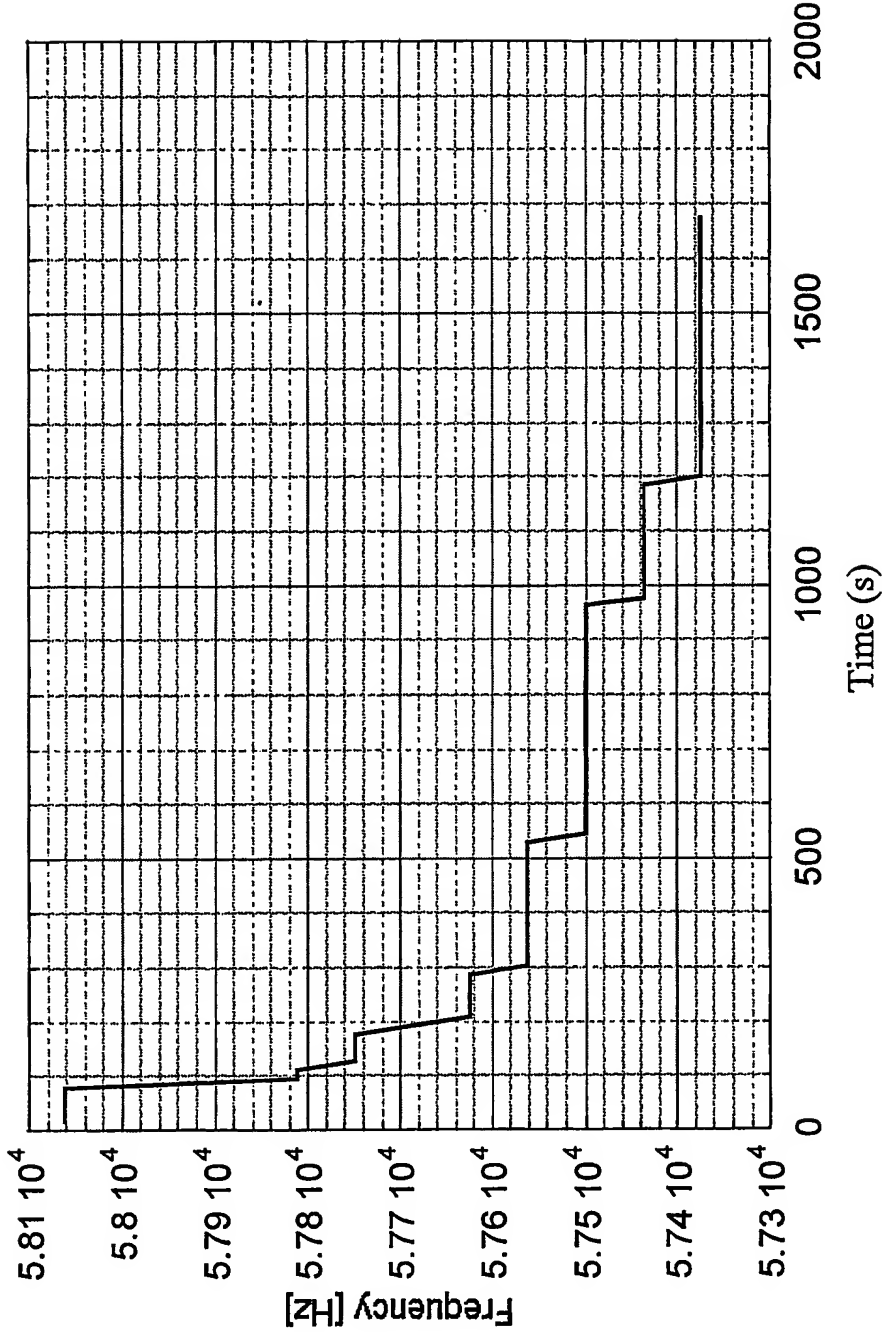


Figure 16/25

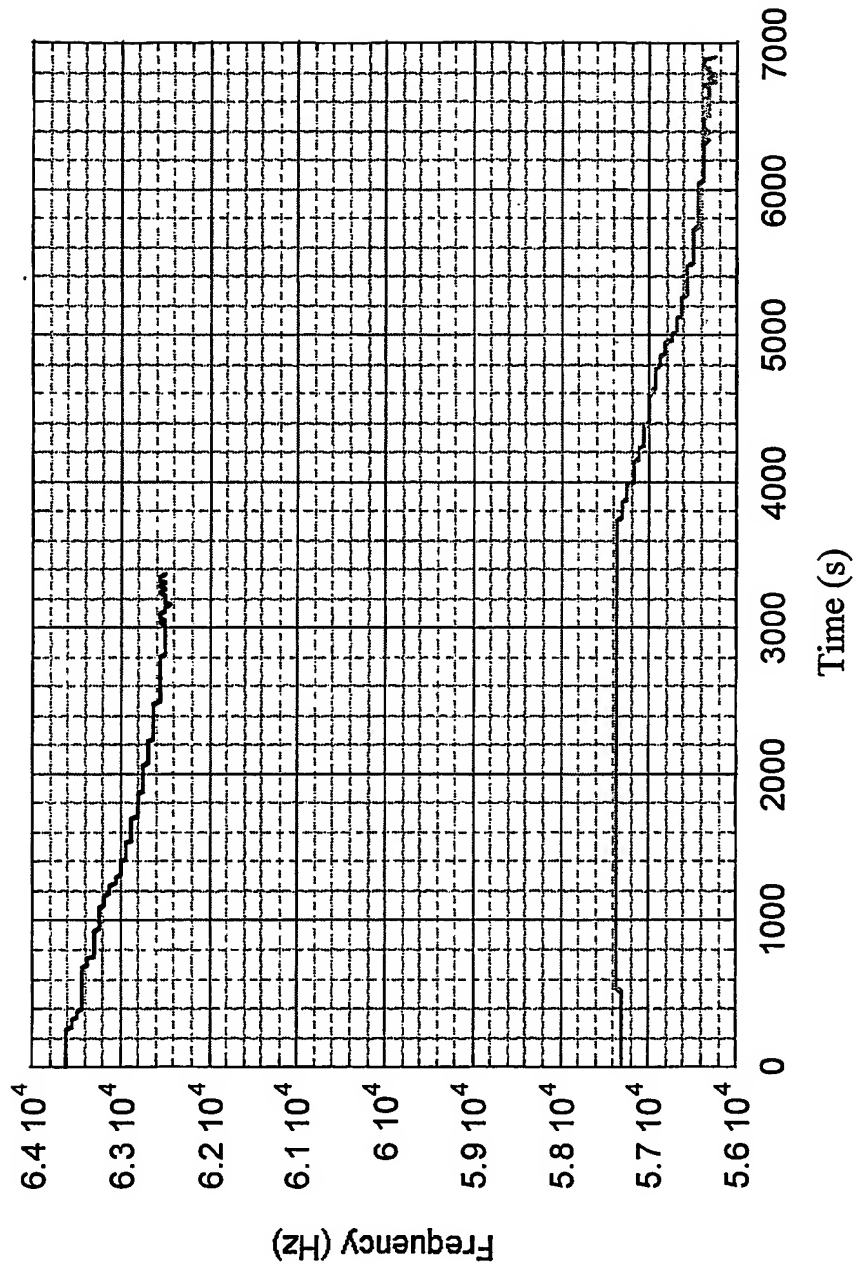


Figure 17/25

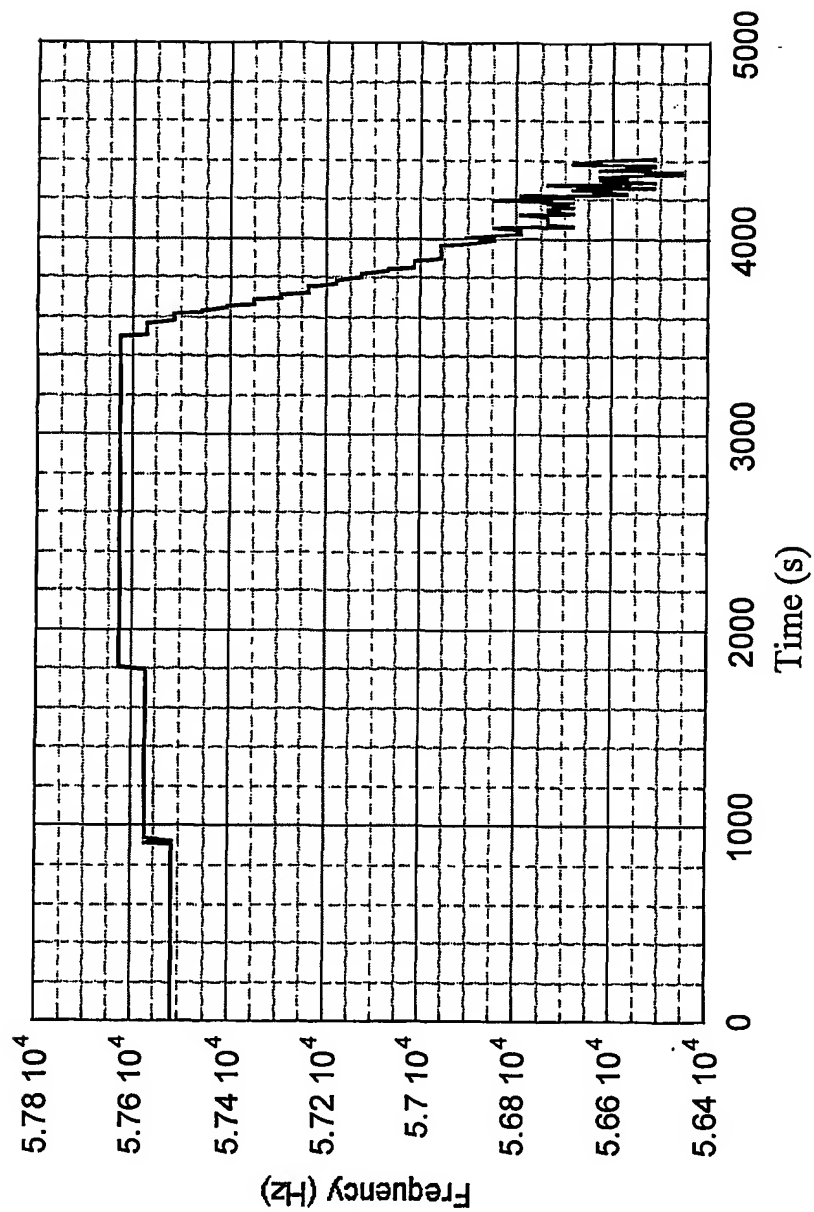


Figure 18/25

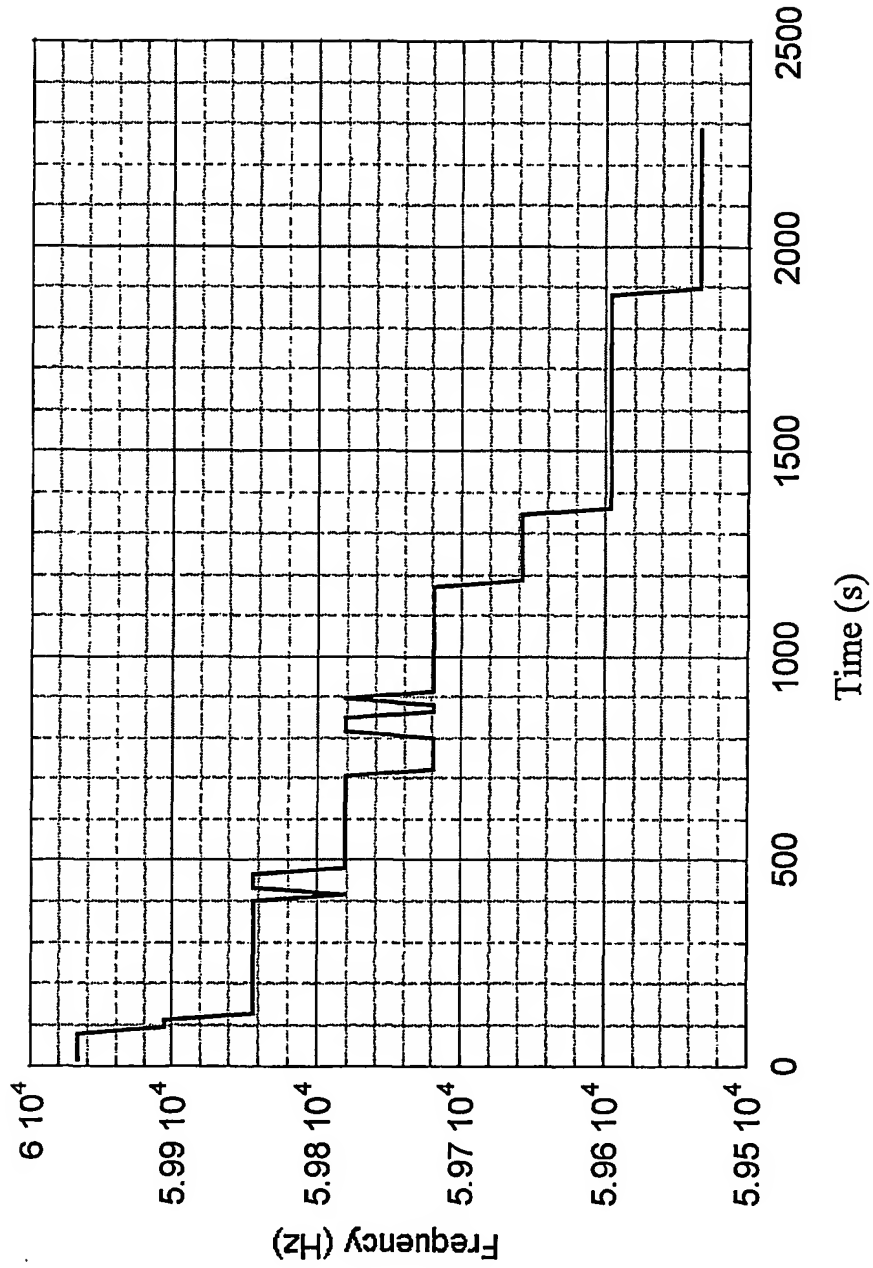


Figure 19/25

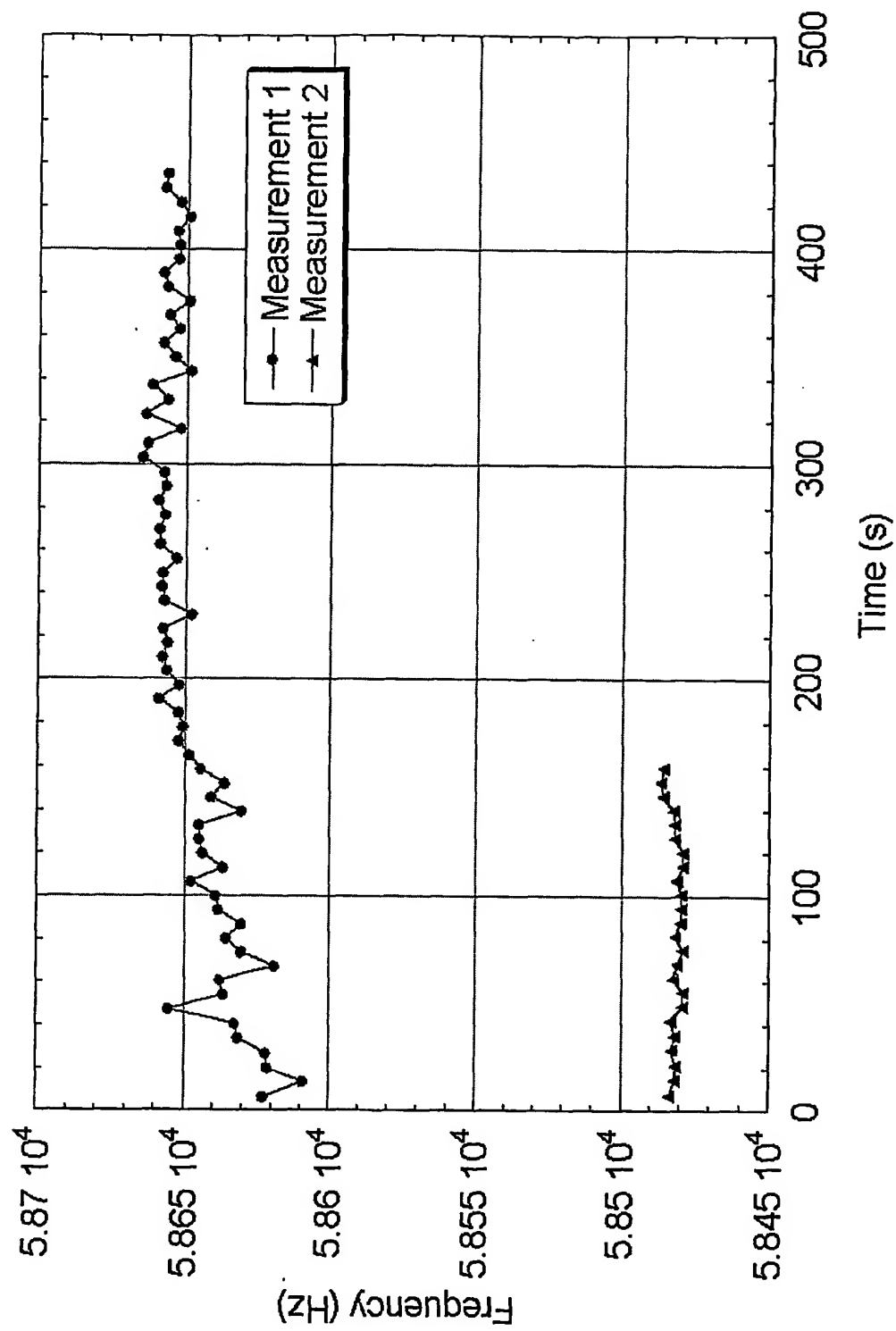


Figure 20/25

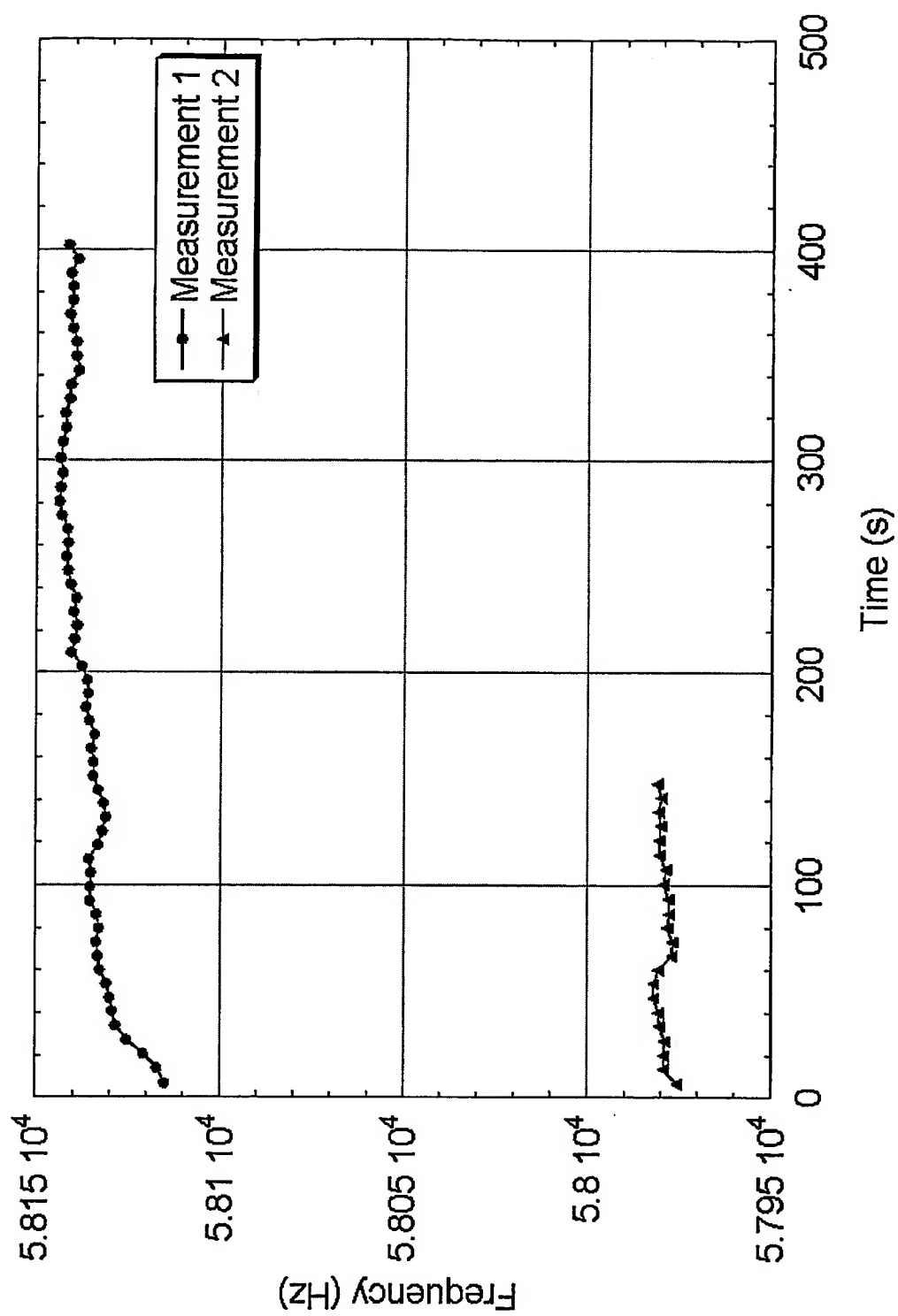


Figure 21/25

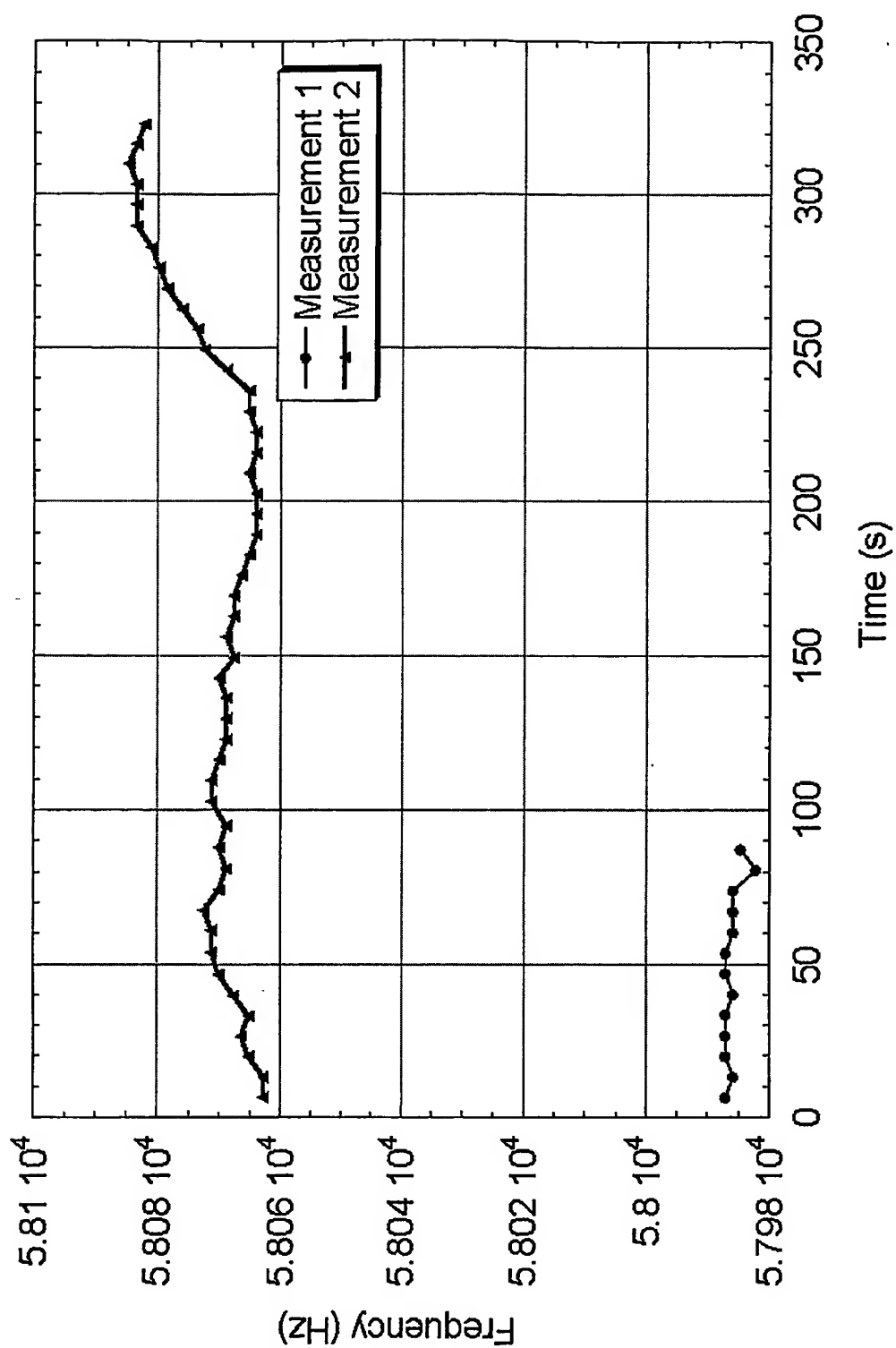


Figure 22/25



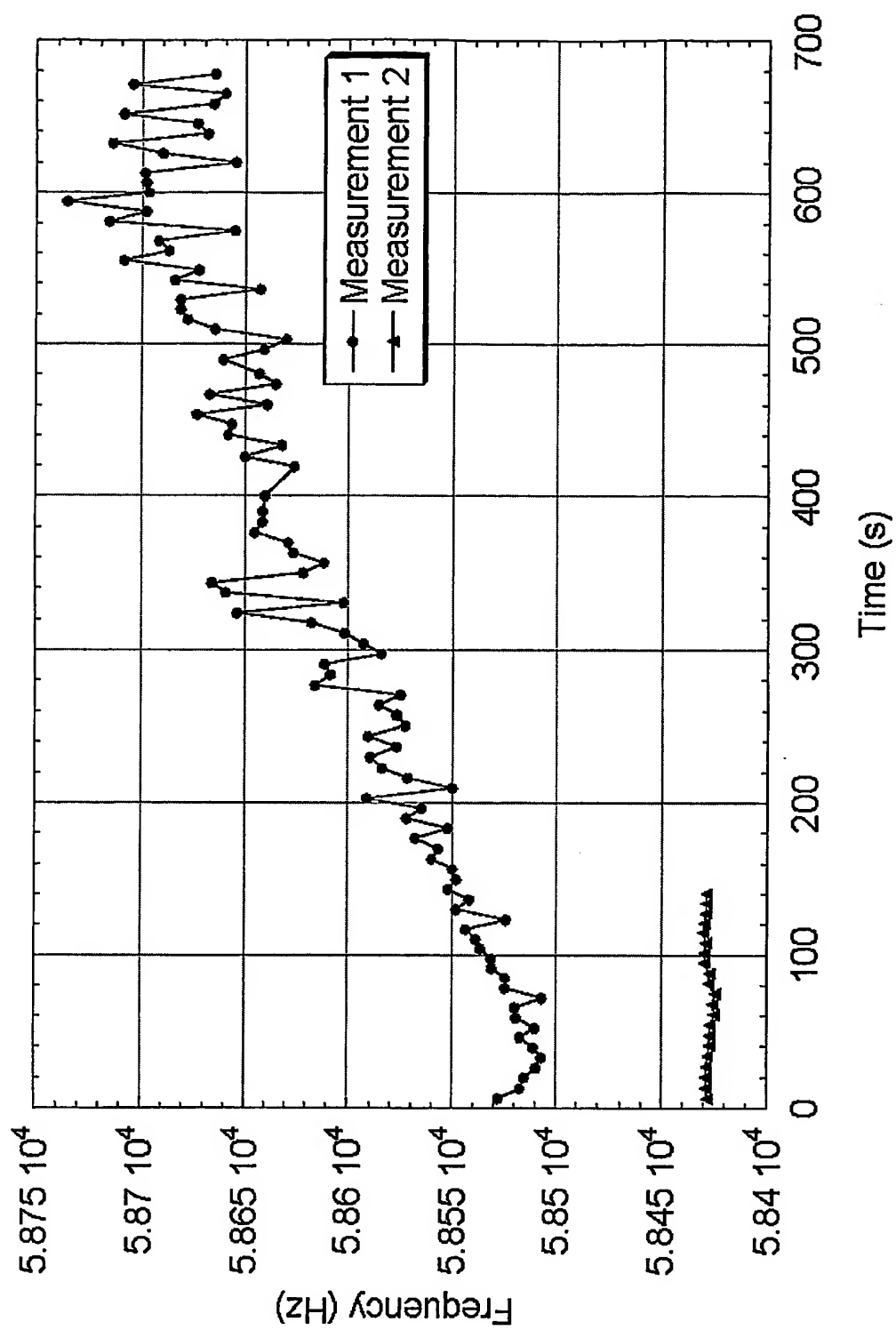


Figure 23/25

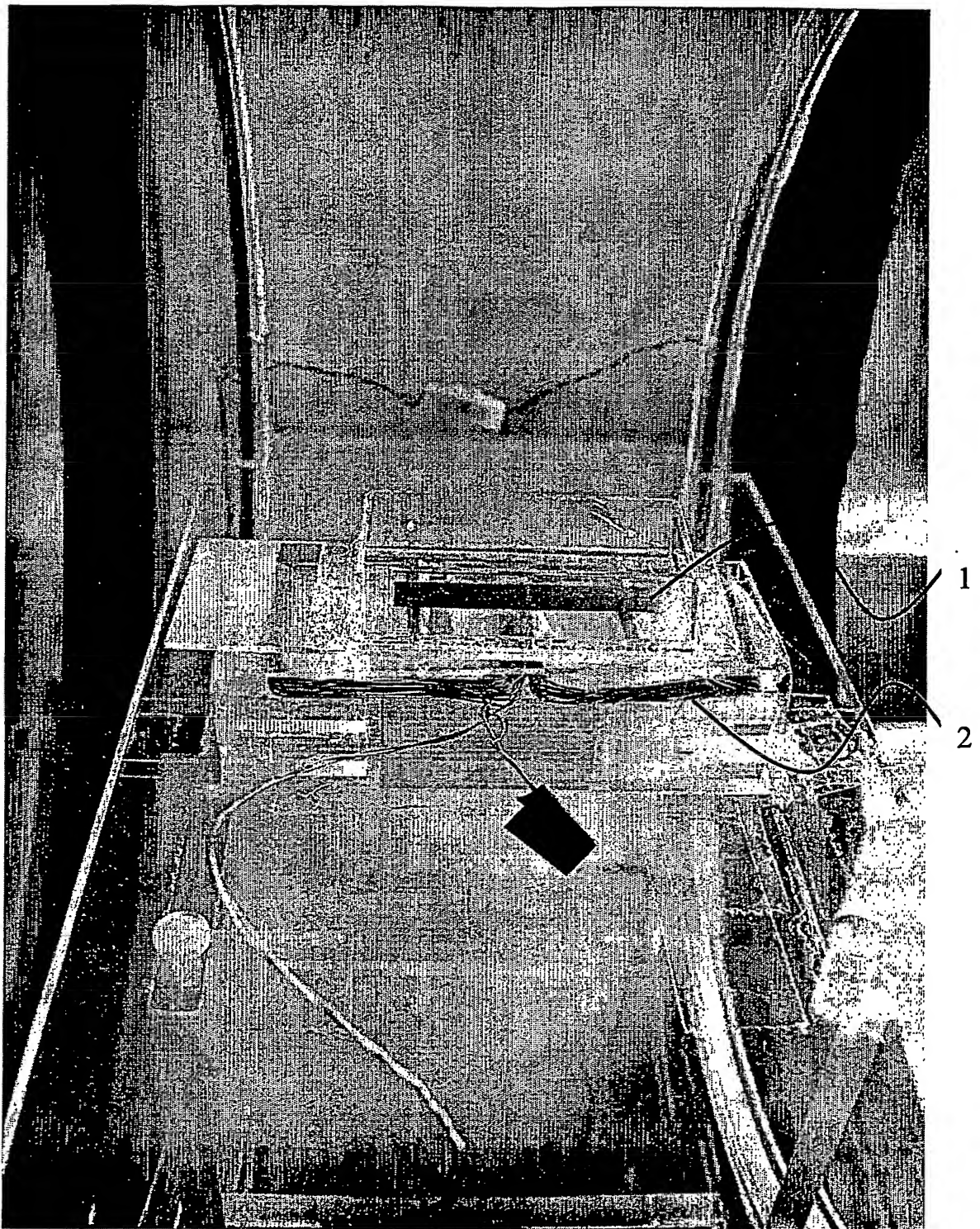


Figure 24/25

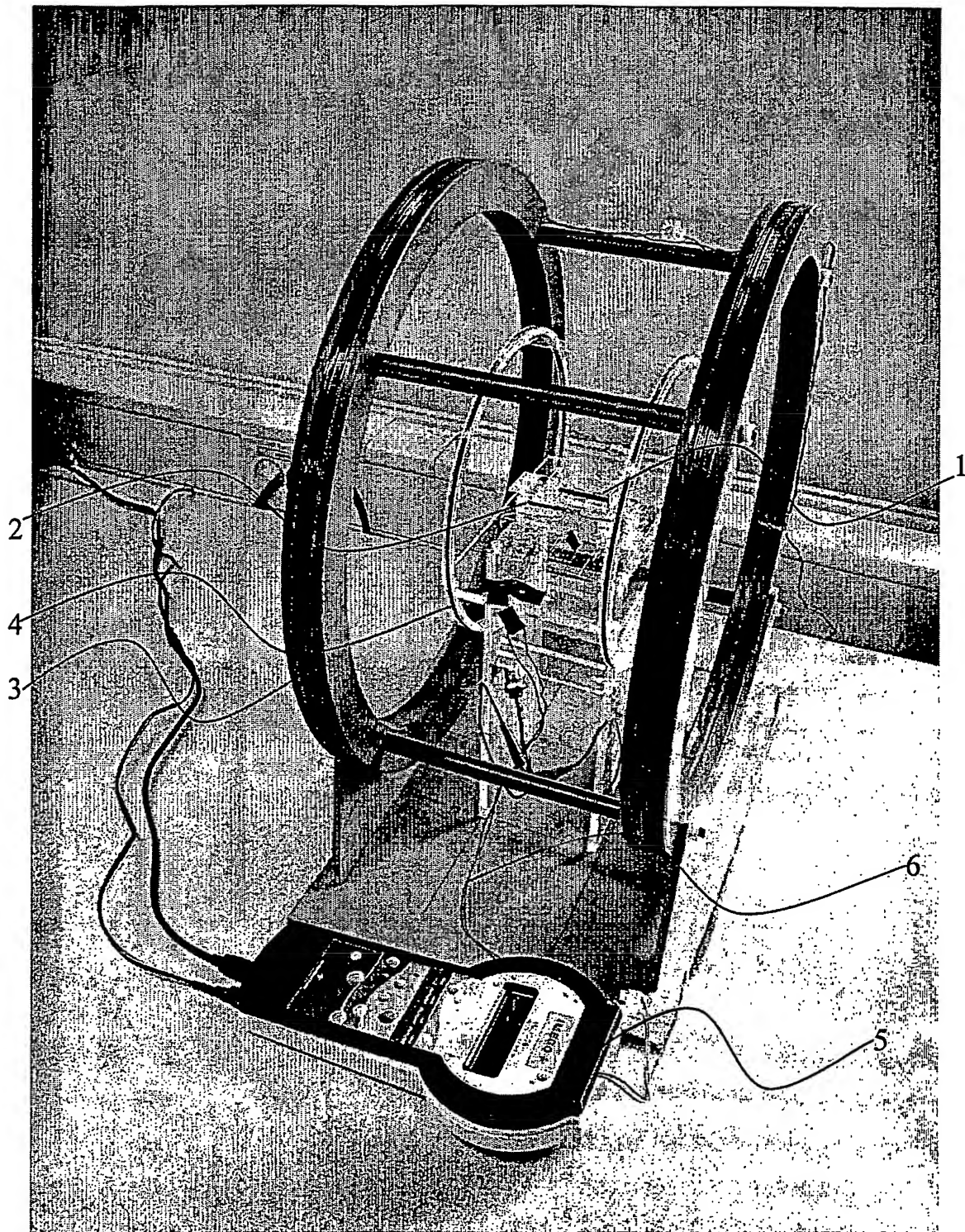


Figure 25/25

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 03/01380

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: A61F 13/42

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61F, G01N, G08B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 03027636 A2 (SYSMORE, INC.), 3 April 2003 (03.04.03), page 3, line 11 - page 6, line 26; page 10, line 8 - line 30	1-4,6,7, 10-21
P,A	--	5,9
P,X	WO 02078513 A2 (AUGMENTECH, INC.), 10 October 2002 (10.10.02), page 13, paragraph [0076] - page 14, paragraph [0079]; page 18, paragraph [0092] - page 19, paragraph [0094]	1-4,6,7, 10-21
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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

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"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

Date of mailing of the international search report

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## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0000233 A1 (THE PROCTER & GAMBLE COMPANY), 6 January 2000 (06.01.00), page 15, line 26 - page 16, line 12; page 19, line 4 - page 21, line 28; page 27, line 10 - line 21, cited in the application	1-7,10-16
A	--	17-21
X	GRIMES, C.A et al. "Thin-Film Magnetoelastic Microsensors for Remote Query Biomedical Monitoring". BIOMEDICAL MICRODEVICES, 1999, No. 2:1, pages 51-60, see pages 51-53, cited in the application.	17-20
A	--	1-7,10-16
A	GRIMES, C.A. et al. "Remote query measurement of pressure, fluid-flow velocity, and humidity using magnetoelastic thick-film sensors". SENSORS AND ACTUATORS, 2000, No. 84, pages 205-212.	1-21
A	--	
A	US 5570082 A (MAHGEREFTEH, N. ET AL), 29 October 1996 (29.10.96), the whole document	1-21
	-- -----	

## INTERNATIONAL SEARCH REPORT

Information on patent family members

06/09/03

International application No.

PCT/SE 03/01380

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
WO	03027636	A2	03/04/03	US	2003060789 A	27/03/03
-----						
WO	02078513	A2	10/10/02	US	2002145525 A	10/10/02
				US	2002145526 A	10/10/02
-----						

## INTERNATIONAL SEARCH REPORT

Information on patent family members

06/09/03

International application No.

PCT/SE 03/01380

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
WO	0000233	A1	06/01/00	AU 1462400 A	22/05/00
				AU 4842199 A	17/01/00
				BR 9911750 A	03/04/01
				BR 9914873 A	13/11/01
				CA 2336025 A	06/01/00
				CA 2347436 A	11/05/00
				CN 1323226 T	21/11/01
				CN 1328476 T	26/12/01
				CZ 20004751 A	15/08/01
				CZ 20011307 A	15/08/01
				EP 0997125 A	03/05/00
				EP 1091773 A	18/04/01
				EP 1124588 A	22/08/01
				HU 0103186 A	28/01/02
				HU 0104106 A	28/03/02
				IL 142558 D	00/00/00
				JP 2002528736 T	03/09/02
				JP 2003520615 T	08/07/03
				TR 200003819 T	00/00/00
				TR 200101148 T	00/00/00
				TW 421587 B	00/00/00
				TW 436281 B	00/00/00
				WO 0025836 A	11/05/00
				ZA 200102779 A	04/07/02
				AU 4728099 A	17/01/00
				AU 4840799 A	17/01/00
				AU 4840899 A	17/01/00
				AU 4842099 A	17/01/00
				AU 4842299 A	17/01/00
				AU 4850499 A	17/01/00
				BR 9911634 A	02/10/01
				BR 9911748 A	03/04/01
				CA 2333699 A	06/01/00
				CA 2335334 A	06/01/00
				CA 2335792 A	06/01/00
				CA 2335991 A	06/01/00
				CA 2336020 A	06/01/00
				CA 2336094 A	06/01/00
				CN 1309547 T	22/08/01
				CN 1314822 T	26/09/01
				CZ 20004852 A	15/08/01
				EP 1089770 A	11/04/01
				EP 1091687 A	18/04/01
				EP 1091688 A	18/04/01
				EP 1091718 A	18/04/01
				EP 1091772 A	18/04/01
				EP 1092151 A	18/04/01
				HU 0103378 A	28/12/01
				IL 140294 D	00/00/00
				JP 2002519089 T	02/07/02
				JP 2002519090 T	02/07/02
				JP 2002519108 T	02/07/02
				JP 2002519112 T	02/07/02
				JP 2002519118 T	02/07/02
				JP 2003524756 T	19/08/03

## INTERNATIONAL SEARCH REPORT

Information on patent family members

06/09/03

International application No.

PCT/SE 03/01380

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
WO	0000233	A1	06/01/00	TR 200100301 T	00/00/00
				TW 408013 B	00/00/00
				TW 413628 B	00/00/00
				TW 426511 B	00/00/00
				TW 519487 B	00/00/00
				US 6149636 A	21/11/00
				US 6266557 B	24/07/01
				US 6342037 B	29/01/02
				US 6359190 B	19/03/02
				US 6372951 B	16/04/02
				US 6395955 B	28/05/02
				US 6399853 B	04/06/02
				US 6407308 B	18/06/02
				US 6423044 B	23/07/02
				US 6433244 B	13/08/02
				US 6570053 B	27/05/03
				US 2002019615 A	14/02/02
				WO 0000082 A	06/01/00
				WO 0000083 A	06/01/00
				WO 0000148 A	06/01/00
				WO 0000226 A	06/01/00
				WO 0000232 A	06/01/00
				WO 0000822 A	06/01/00
				ZA 200007366 A	11/12/01
				ZA 200007464 A	06/09/01
				AT 246911 T	15/08/03
				AU 4725299 A	17/01/00
				AU 4962299 A	17/01/00
				BR 9911749 A	03/04/01
				CA 2334984 A	06/01/00
				CA 2336068 A	06/01/00
				CN 1313743 T	19/09/01
				DE 69910387 D	00/00/00
				EP 1091716 A,B	18/04/01
				EP 1093352 A	25/04/01
				JP 2002519105 T	02/07/02
				JP 2002519107 T	02/07/02
				TW 416842 B	00/00/00
				TW 482662 B	00/00/00
				US 6186991 B	13/02/01
				US 6257585 B	10/07/01
				US 6306041 B	23/10/01
				US 6432097 B	13/08/02
				US 6450889 B	17/09/02
				WO 0000137 A	06/01/00
				WO 0000145 A	06/01/00
				AU 4850599 A	17/01/00
				CA 2333957 A	06/01/00
				EP 1091720 A	18/04/01
				JP 2002519110 T	02/07/02
				TW 416843 B	00/00/00
				US 6384296 B	07/05/02
				WO 0000151 A	06/01/00
				AU 4492400 A	10/11/00
				AU 4665800 A	10/11/00



## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

06/09/03

PCT/SE 03/01380

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
WO	0000233	A1	06/01/00	AU	4665900 A	10/11/00
				AU	4802900 A	10/11/00
				AU	4803000 A	10/11/00
				BR	0010058 A	15/01/02
				BR	0010059 A	15/01/02
				CA	2367588 A	02/11/00
				CA	2370502 A	02/11/00
				CA	2370509 A	02/11/00
				CA	2370739 A	02/11/00
				CA	2370936 A	02/11/00
				CN	1348501 T	08/05/02
				CN	1349562 T	15/05/02
				EP	1173605 A	23/01/02
				EP	1173606 A	23/01/02
				EP	1173618 A	23/01/02
				EP	1173758 A	23/01/02
				EP	1173759 A	23/01/02
				JP	2002542843 T	17/12/02
				JP	2002542845 T	17/12/02
				JP	2002542846 T	17/12/02
				JP	2002543397 T	17/12/02
				JP	2003517584 T	27/05/03
				WO	0065083 A	02/11/00
				WO	0065084 A	02/11/00
				WO	0065096 A	02/11/00
				WO	0065347 A	02/11/00
				WO	0065348 A	02/11/00
				ZA	200108416 A	17/03/03
<hr/>						
US	5570082	A	29/10/96	WO	9714127 A	17/04/97
<hr/>						